MSC-PA-R-69-2
SUPPLEMENT 11

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 9 MISSION REPORT
SUPPLEMENT 11

COMMUNICATIONS SYSTEM PERFORMANCE

(NASA-TM-X-69434) APOLLO 9 MISSION REPORT. SUPPLEMENT 11: COMMUNICATIONS SYSTEM PERFORMANCE Final Report (NASA) 100 p

N74-70880

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MANNED SPACECRAFT CENTER
HOUSTON, TEXAS
DECEMBER 1969

MSC-PA-R-69-2
Supplement 11

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COMMUNICATIONS SYSTEM PERFORMANCE

PREPARED BY

Lockheed Electronics Company

APPROVED BY

James A. McDivitt
Manager, Apollo Spacecraft Program

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS
December 1969

EE-69-3715 (U)

FINAL REPORT ON
COMMUNICATIONS SYSTEM PERFORMANCE
DURING THE APOLLO 9 MISSION
REVISION 1

Approved For Distribution By: M. L. Trauddin for
Howard C. Kyle, Technical Manager
Apollo Communications System

Prepared by:
Lockheed Electronics Company
Houston Aerospace Systems Division
Houston, Texas
Under Contract NAS 9-5191
For
National Aeronautics and Space Administration
Manned Spacecraft Center
Houston, Texas

PREFACE

This final report on the communications system performance during the Apollo 9 Mission has been prepared for the Tele/Communications Systems Division (TCSD) of NASA's Manned Spacecraft Center under Contract NAS 9-5191. The information in this document is primarily a discussion of data not available when the Apollo 9 Mission report was published. The document also contains results of special investigations not previously reported.

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1.0 APOLLO 9 COMMUNICATIONS EVALUATION INTRODUCTION

1.1 General

Communication events or mission events involving high communications system utilization are discussed in this report. Periods of nominal communications system performance are generally not discussed; however, the performance during important communications events is summarized in Table III and Table IV of Appendix A. Appendix B lists the Apollo 9 mission communications objectives. This report is supplement no. 11 to the Apollo 9 Mission Report (MSC-PA-R-69-2) dated May 1969.

This section summarizes the Apollo 9 communications systems performance and highlights the important aspects of the mission.

Sections II and III present the communication system performance resulting from detailed evaluations of important communications system checks, mission events or discrepancies.

1.2 Communications Evaluation Summary

Performance of the communications systems was generally satisfactory. However, several problems degraded the overall system performance and temporarily inhibited voice, telemetry, command, or tracking capability.

Pictures of excellent quality were received during the two television transmissions from the lunar module. Voice quality was good throughout the rendezvous phase and during most of the mission. However, on several occasions, procedural errors or improper equipment configurations prevented communications between the Mission Control Center and the spacecraft. A communication check using the backup S-band voice signal combinations was performed over the Carnarvon station during the first revolution. Good quality voice was received by both the spacecraft and the station; however, the downlink voice was not remoted to the Mission Control Center.

The first communications problem occurred during the launch phase. As shown in Figure 2-1, procedural errors at the Grand Bahama Island station degraded the S-band system performance between 00:02:00 and 00:02:32 GET, when the ground receiver locked on to a 51.2-kHz spurious signal in the downlink spectrum, and between 00:02:32 and 00:03:17 GET, when the antenna tracked a sidelobe. S-band communications were completely lost between 00:05:01 and 00:06:00 GET because the operator of the ground transmitter interrupted transmissions 30 seconds early. At 0:05:12, the operator recognized the error and energized the transmitter, but was unsuccessful in reestablishing two-way lock. At 00:05:30 the Bermuda station initiated uplink transmissions as scheduled. The spacecraft transponder immediately locked to the Bermuda signal; however, solid two-way phase lock was not established until 00:06:00.

During the first television transmission, no voice was received at the Mission Control Center until the Merritt Island station was requested to remote VHF voice instead of S-band voice. S-band voice was received and recorded at Merritt Island, but the transmission to the Mission Control Center was inhibited by improper configuration within the station.

Excellent quality voice transmissions were received from each of the lunar module crewmen during the extravehicular activity. However, the crew did not receive Mission Control Center transmissions relayed through the Texas, Merritt Island, Bermuda, and USNS Vanguard stations. Only one of the transmissions relayed through the Guaymas station was received by the crew. Because of improper configurations at the Guaymas, Texas, Merritt Island, and USNS Vanguard stations, all voice transmissions, except one, were on the S-band uplink only. Reception of the S-band transmissions was inhibited, as planned, by the spacecraft volume-control settings being at full decrease. Voice transmissions through

Bermuda were unsuccessful because they occurred during intervehicular communications when the VHF receivers were captured. Good quality uplink voice was received by each crewmen through the USNS Huntsville, USNS Redstone, and Canary Island stations.

Telemetry data and voice were recorded onboard when the command module was outside the network coverage area. Solid frame synchronization was provided by the telemetry decommutation system during most of the data playbacks. The quality of the recorded voice was dependent on the playback-to-record speed ratio of the data storage equipment and on the network station which received the playbacks. Several single S-band stations reported high-level tone interference in the received voice with a playback-to-record ratio of 32. These stations were using a new receiver that was installed to support a dual-vehicle earth orbital mission. Data indicate that the interference was caused by an intermediate-frequency amplifier with insufficient bandwidth to accommodate the combination of the modulation spectrum, Doppler, spacecraft transmitter frequency offset, and spacecraft transmitter short-term frequency stability.

The transceiver and power amplifier switching associated with lunar module secondary S-band checks caused several signal dropouts during the Antigua and Carnarvon coverage of revolutions 29 and 32. Since Antigua is a single S-band station and was attempting to support both vehicles, some data were lost.

Invalid S-band range-code acquisitions were reported by the Goldstone, Honeysuckle, and Texas stations during their coverage of lunar module operations. The range-code acquisition problems during Goldstone coverage of revolutions 31 and 32 were caused by false uplink phase locks. The inability of the Texas station to acquire a valid range-code during the ascent engine firing to depletion was caused by use of an incorrect uplink range-code modulation index. Refer to section 3.5 for further detail.

The performance of the lunar module command system was good throughtout lunar module operations. The performance of the command module S-band command system was satisfactory, except for the time period from 109:21:50 to 118:46:53 GET. Verification of spacecraft acceptance of real-time commands was not detected by the ground stations during this period. The data indicate that the commands were being properly encoded and transmitted. Subsequently, the crew was able to correct the problem. Section 3.6 provide additional details on this descrepancy. The lunar module S-band steerable antenna was not functionally tested during the mission.

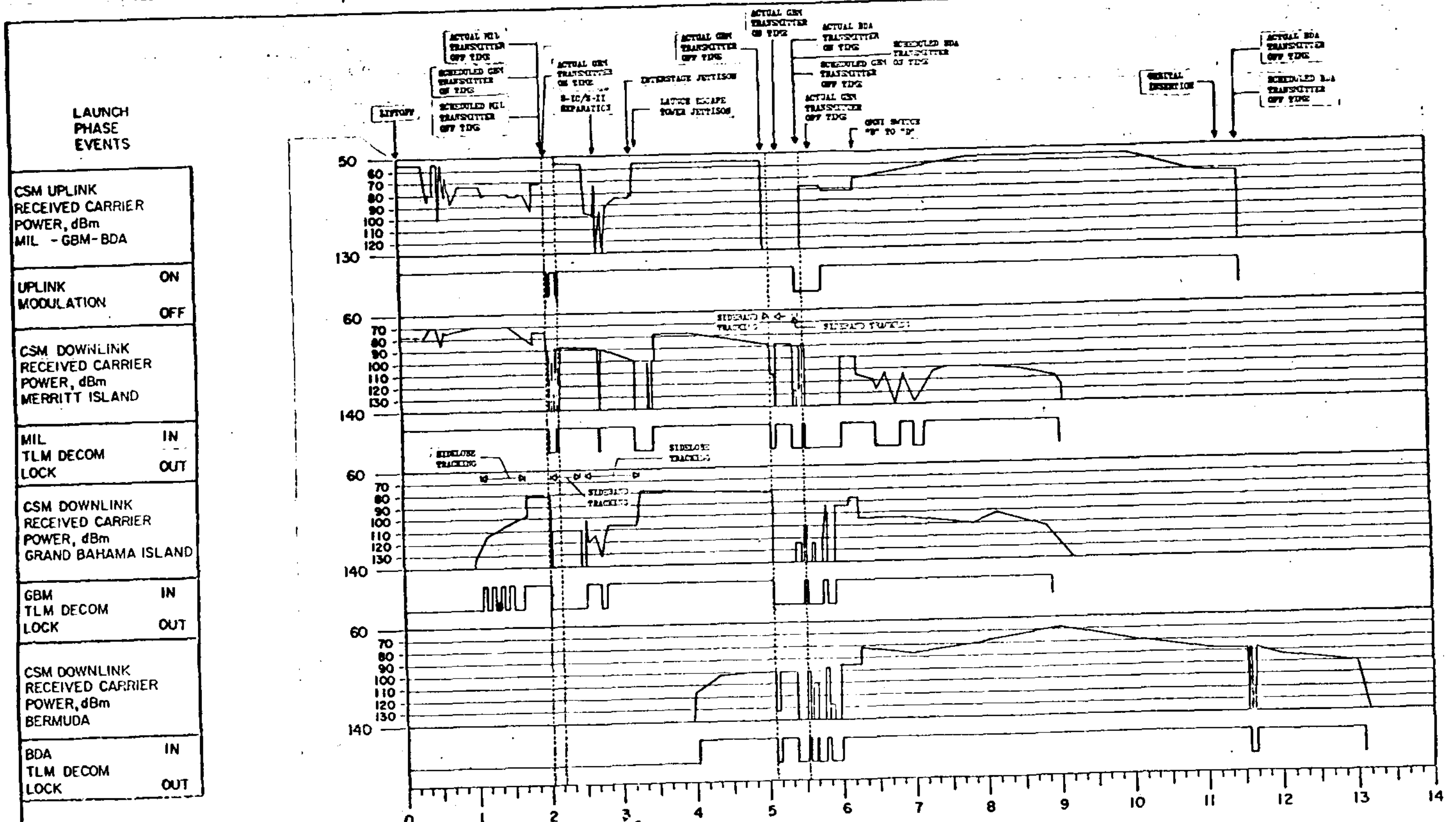
The command and service-module high-gain antenna was acquired and tracked successfully during the Carnarvon and Hawaii station coverage during revolution 122. The received uplink and downlink carrier power during both passes corresponded with preflight predictions.

2.0 APOLLO 9 COMMUNICATIONS SYSTEMS EVALUATION

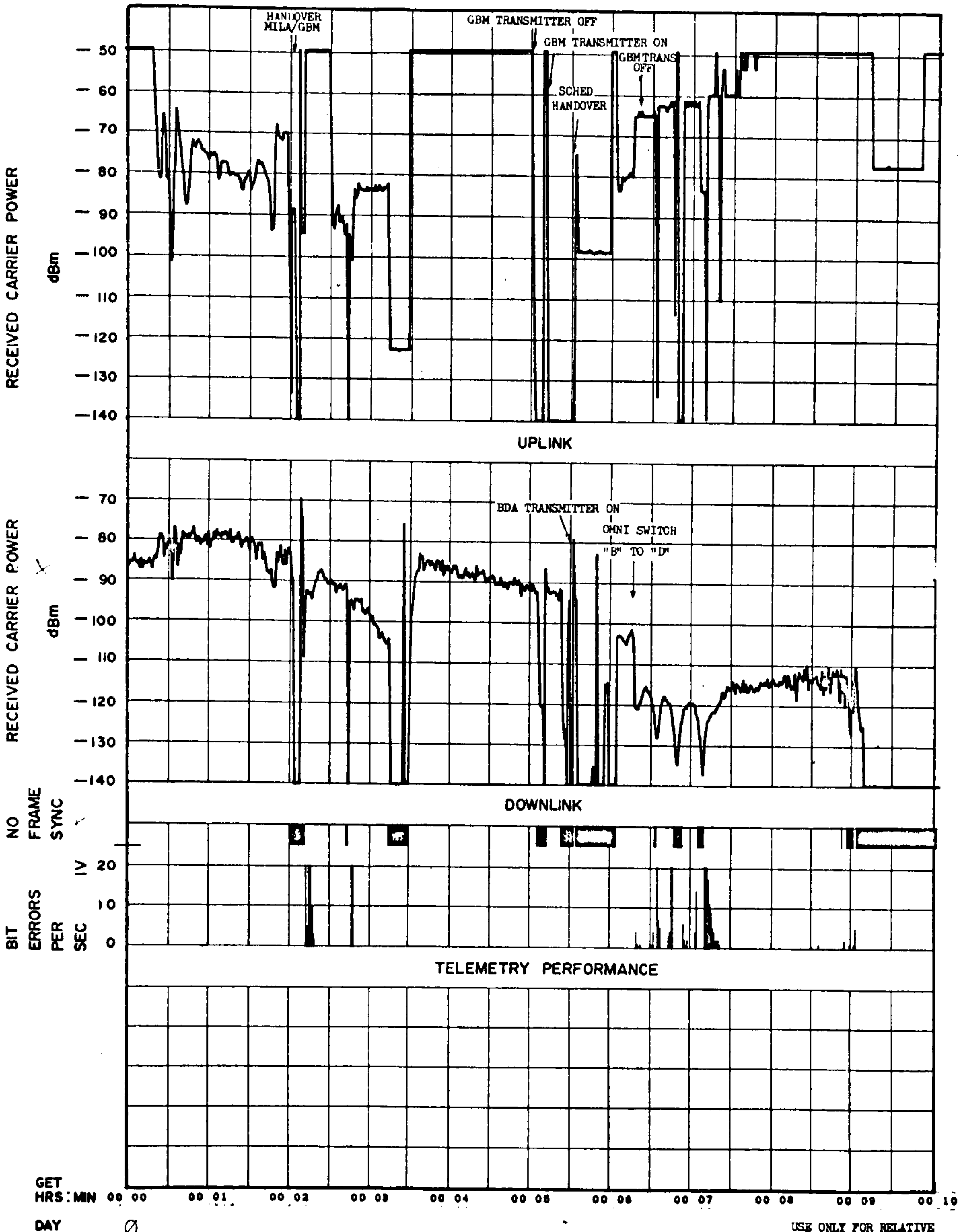
2.1 Launch

The Merritt Island site provided two-way S-band communications support of the command service module during the terminal portion of the count-down, liftoff, and for the first two minutes of the mission. As shown in Figure 2-1, Merritt Island handed over the S-band uplink to the Grand Bahama site, but Grand Bahama Island failed to acquire uplink lock until approximately 000:02:10 GET. The spacecraft transponder switched to the auxilliary oscillator which caused Merritt Island to lose the signal at 000:02:03. Merritt Island re-acquired the downlink signal at 000:02:10 and had loss-of-signal from 000:02:43.5 to 000:02:44.5 (S-IC/S-II separation and S-II ignition) and from 000:03:14.5 to 000:03:29 (interstage jettison). The site continued solid downlink passive coverage until 000:05:00, when the spacecraft transponder again switched to the auxilliary oscillator as a result of the premature termination of the uplink by Grand Bahama Island. Merritt Island experienced intermittant reception until the Bermuda site had solid two-way lock at approximately 000:06:03. Merritt Island lost the signal as expected at approximately 000:09:10 GET (Figure 2-2).

S-band downlink voice quality was good during most of the launch phase except for short periods when lock was lost. Three short transmissions at 000:02:04, 000:03:16, and 000:03:18 were not heard on the S-band downlink voice but were heard on the VHF downlink. No other complete downlink transmission was lost, but words were dropped at random from sentences on the S-band downlink at 000:03:27, 000:04:10, and 000:04:17. The loss of these words could not be attributed to the loss of the S-band signal. VHF downlink voice was good until 000:03:24 GET. No further downlink transmissions were recorded after this time. The Merritt Island voice recording was terminated because the squelch on the receivers was improperly adjusted.



USB COMMUNICATIONS PERFORMANCE
APOLLO 9 - LAUNCH
FIGURE 2-1



MILLAUNCH

USE ONLY FOR RELATIVE MEASUREMENTS
CAL DATA INACCURATE

SEQ. NO. 25Ø SYSTEM USB LINK: UP MODE 06

APOLLO 9 ANTENNA 30' /OMNI DOWN MODE 02

3

FIGURE 2-2 CSM S-BAND COMMUNICATIONS PERFORMANCE DURING MIL COVERAGE AT LAUNCH

Grand Bahama Island acquired the downlink signal at 000:01:00 GET and tracked on a side lobe until 000:01:42.5. At the scheduled Merritt Island to Grand Bahama Island handover time, Grand Bahama Island power amplifier came on with no apparent exciter sweep prior to power amplifier turn on. As shown in Figure 2-1, Grand Bahama Island failed to acquire uplink lock as a result of this procedural error, and the spacecraft transponder switched to the auxilliary oscillator, causing loss of downlink lock. Grand Bahama Island experienced a sideband lock from 000:02:03 to 000:02:32 which caused the telemetry decommutator to be out of lock. At this time, the station antenna was again tracking on a side lobe (20 dBm below main lobe boresight gain). At 000:03:17, main antenna boresight tracking was accomplished and was apparent in both uplink and downlink carrier power levels.

Grand Bahama maintained solid two-way levels until 000:05:01, at which time the transmitter was prematurely turned off. Transmitter power was restored at 000:05:12 and was left on until 000:05:40. Bermuda Island turned on their transmitter at 000:05:30 (as scheduled) and reached full power amplifier output at 000:05:31. The Bermuda Island site transmitter captured the transponder at 000:05:31. Grand Bahama Island re-acquired downlink lock at 000:05:56 apparently on a subcarrier spur. A step increase in downlink receiver 1 carrier power of 7.5 dB occurred at 000:06:08.5. This step increase was not observed in the receiver 2 carrier power. Both receiver 1 and 2 were covering the command service module downlink. Receiver 2 was apparently on the acquisition antenna from acquisition of signal until it was switched to the main antenna at 000:06:46. Grand Bahama Island experienced loss of signal on receiver 1 and 2 at 000:09:13 as expected.

As shown in Figure 2-3, Bermuda Island acquisition of signal occurred at 000:03:59 GET. At 000:05:01, the transponder switched to auxilliary oscillator because Grand Bahama Island terminated the uplink early. Bermuda Island lost approximately 4 seconds of data before reacquiring the downlink. At 000:05:23, the acquisition tracking receiver (tuned to the S-IVB instrumentation unit/command and communication system (IU/CCS) transponder experienced weak signals and large error components in the autotracking mode. The antenna slewed off boresight into a null of the main antenna and caused subsequent loss of the command service module downlink because of the large fluctuations in the downlink carrier power. Due to the large errors in tracking and switching between autotrack and programmed track, downlink receiver 1 continued to experience intermittent locks until 000:05:59.5. At this time, solid two-way lock and smooth tracking were accomplished. The spacecraft antenna switch from omni B to D was observed from Bermuda Island data as a step increase in uplink and downlink carrier power at 000:06:15. The Bermuda Island to Vanguard handover was accomplished at 000:11:38, and approximately 4 seconds of signal loss was experienced by Bermuda Island during the handover. Bermuda Island final loss of signal occurred at 000:13:08 as expected.

2.2 Insertion to Lunar Module Activation

The command module backup voice was checked at the Carnarvon USB site on revolution 1. Good backup downlink voice was received but it was not remoted to the Mission Control Center. The backup downlink voice taken from the Carnarvon magnetic tapes was of good quality and good intelligibility. The VHF downlink voice was of good quality and good intelligibility.

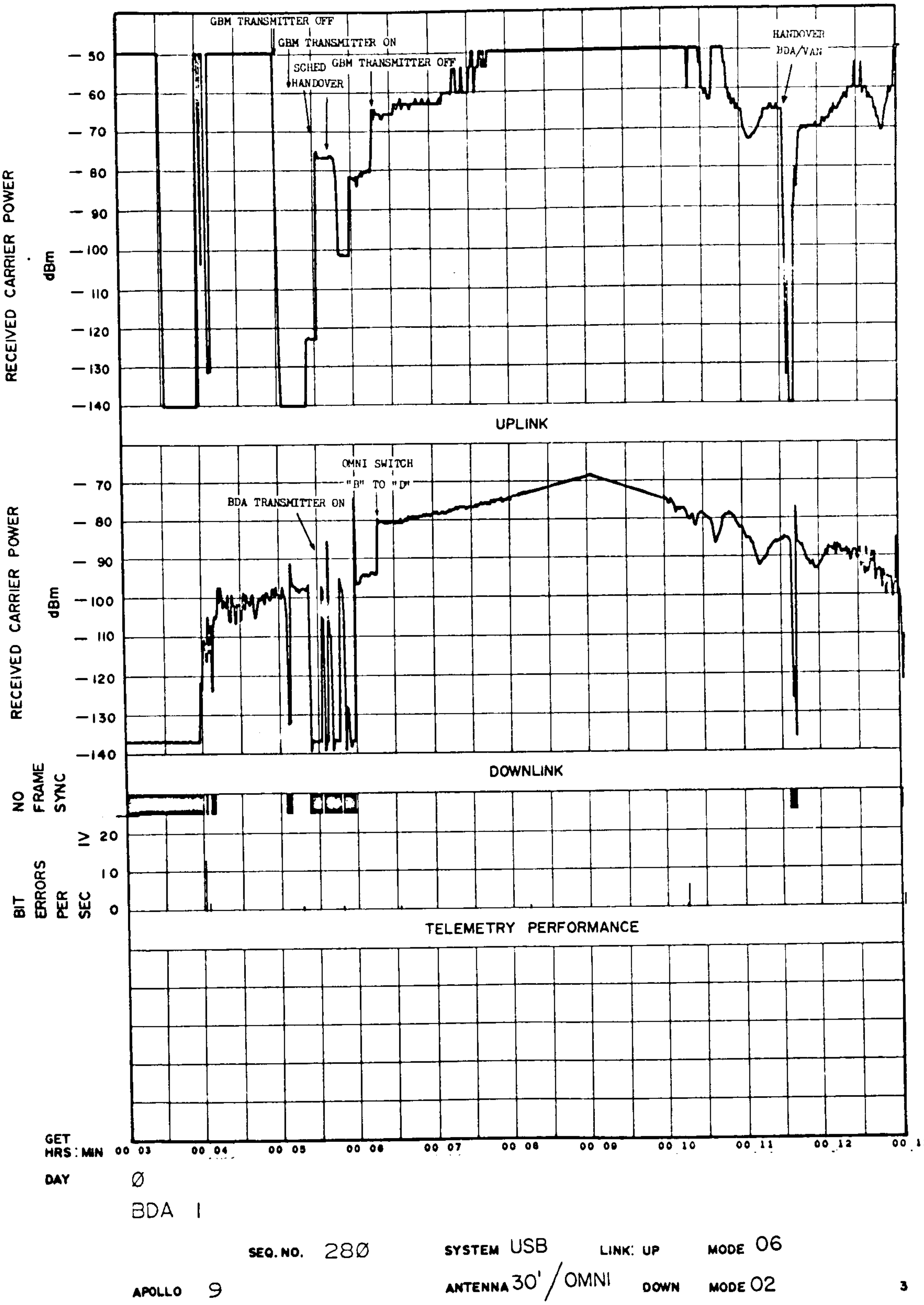


FIGURE 2-3 CSM S-BAND COMMUNICATIONS PERFORMANCE DURING BDA COVERAGE AT LAUNCH

The command module data storage equipment recorded the high acoustic noise during the launch phase. This information was evaluated to determine the effects of the high noise levels on voice communications between the spacecraft and the Manned Space Flight Center (MSFN) at launch (Refer to Section 3.2, for additional information).

Tone interference in the playback voice from the command module data storage equipment was detected during revolution 16 at Guaymas. This interference caused the playback voice to be unusable. An investigation showed that the tone interference was caused by a TR-104 receiver with a narrow bandwidth filter. Other stations with this receiver configuration reported the same problem. During subsequent passes, Guaymas and Texas used a wider bandwidth filter. This configuration eliminated the tone interference in the playback voice (Refer to Section 3.4).

On revolution 17, the USNS Vanguard acquired the command and service module S-band downlink near predicted acquisition of signal (25:23:32). The S-band downlink received carrier power at acquisition of signal was -127 dBm and increased to -107 dBm within 30 seconds. At 025:25:00, the signal level began dropping rapidly to -131 dBm and continued fluctuating rapidly between -130 and -110 dBm. Handover from Bermuda Island to Vanguard was accomplished at 025:25:41. The uplink and downlink S-band carrier power levels continued to fluctuate rapidly with frequent losses of two-way lock. Only a single command was transmitted because of the intermittent two-way locks until the handover to the Canary Island USB site at 25:29:05. Due to the weak signal levels and frequent loss of signals during the Vanguard active coverage, no ranging acquisitions were accomplished.

2.3 LM Activation

The LM S-band communication system was activated during revolution 28. At 043:36:39 the Madrid USB site acquired the lunar module S-band signal and achieved two-way lock. Since coverage was limited due to very low elevation tracking the signal was lost at 043:37:29. Ranging acquisition was not accomplished due to the short period of spacecraft communications coverage.

The second S-band communications contact with the lunar module occurred at the Carnarvon USB site on revolution 28. The S-band communications system performance was satisfactory during this pass. However, the scheduled lunar module steerable antenna check was canceled and was not rescheduled during the lunar module periods of activation.

Functional S-band lunar module communications checks were scheduled to be performed during the Antigua revolution 29 pass. The checks were to verify both the primary S-band transceiver and secondary S-band transceiver with the power amplifiers on and off. As shown in Figure 2-4, Antigua initially acquired the S-band transceiver and two-way lock on a side lobe of the ground station antenna at 044:53:36. Weak downlink carrier power levels and intermittent loss of lock continued during the pass until 044:57:42 when the carrier power level improved and averaged approximately -87 dBm until 044:59:30.

Due to the tracking difficulties experienced by the Antiqua station during the majority of the pass, insufficient data are available to evaluate the lunar module secondary transceiver performance. At no time during the pass was ranging receiver code acquisition accomplished on the primary transceiver. A successful range receiver code acquisition was accomplished during the short period of secondary transceiver two-way lock from 044:57:42 to 044:58:24. Transfer from secondary transceiver was accomplished at 044:58:27. The data analyzed does not indicate activation of the uplink exciter sweep, which resulted in an

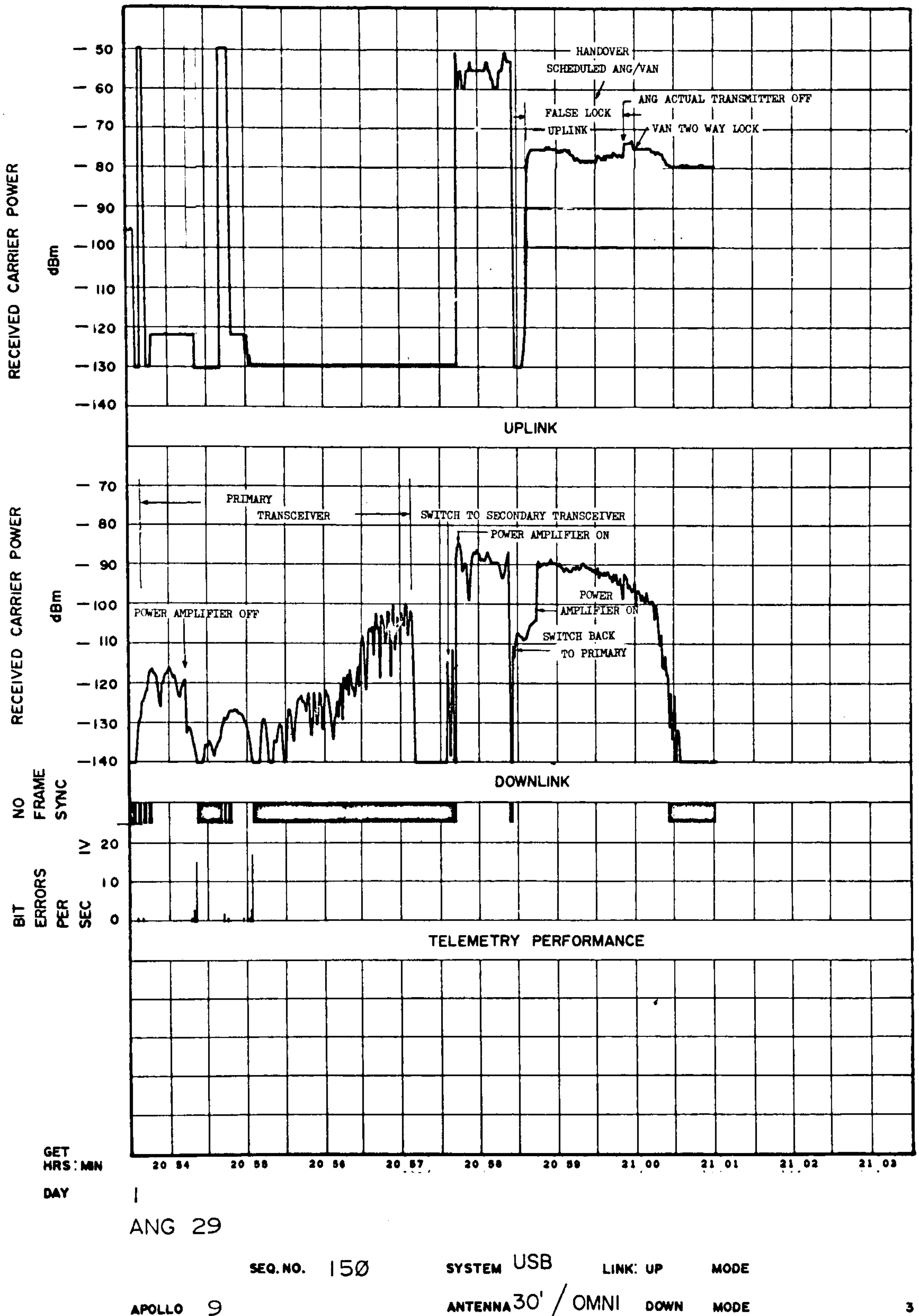
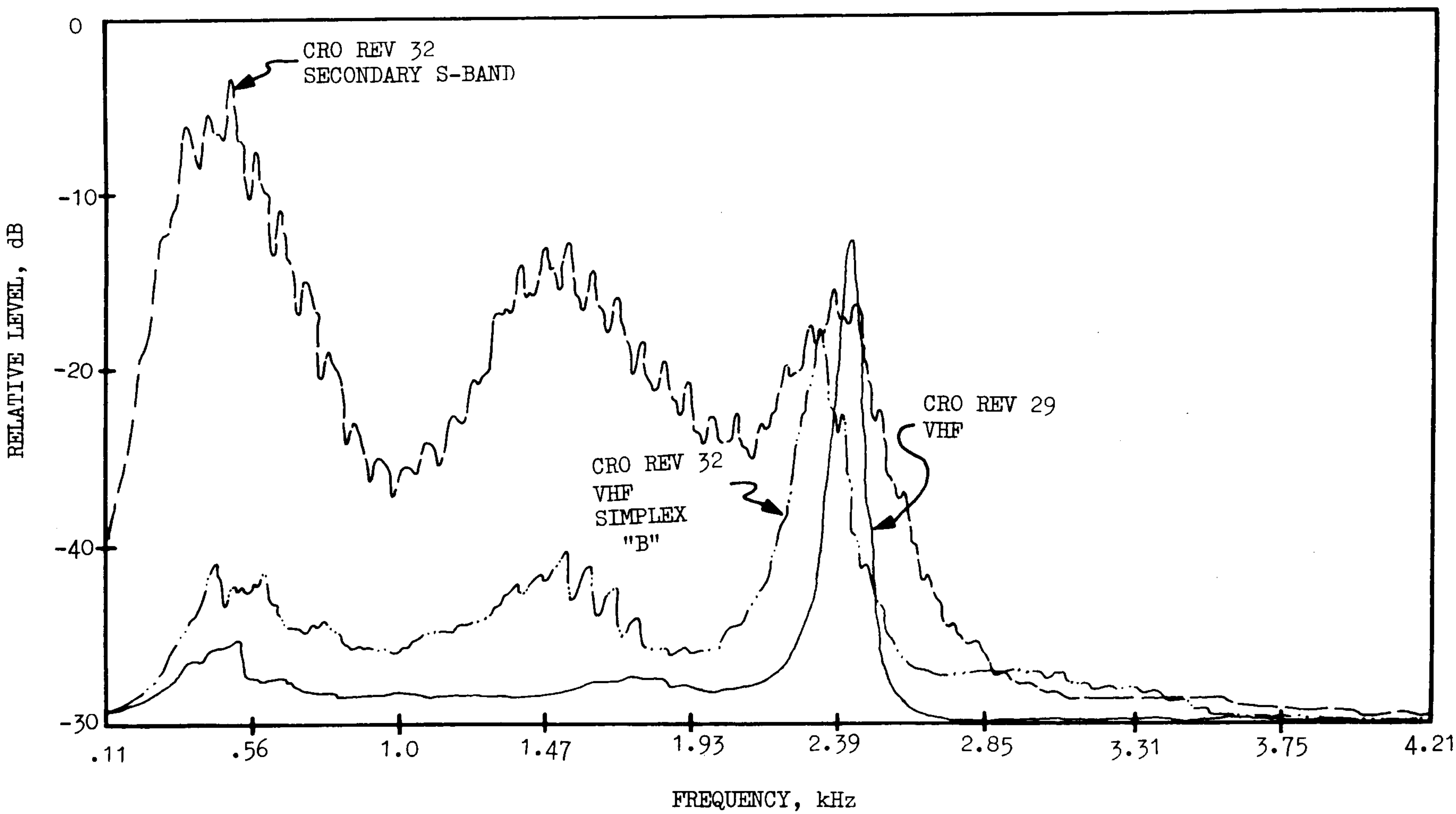


FIGURE 2-4 LM S-BAND COMMUNICATIONS PERFORMANCE DURING COMMUNICATIONS MODE CHECKS

approximate 10-second loss of uplink lock. The spacecraft receiver locked to a subcarrier until handover to Vanguard at 044:59:49. The delay in scheduled handover at 044:59:30 was due to an operator oversight. In addition, during the pass, the crew did not follow secondary S-band procedures step-by-step. They performed two steps at once and only stayed in one configuration for 10 to 20 seconds instead of one minute. This,in itself, caused extreme difficulty for the Manned Space Flight Network station to maintain or acquire lock. The S-band voice was generally better than VHF although voice on VHF was fair in quality and intelligibility. The noise level increased on the VHF link when the crew was transmitting.

S-band downlink communication during revolution 29 coverage at Carnarvon was weak and voice intelligibility was fair. S-band uplink voice to the lunar module was loud and clear. The VHF downlink voice quality was poor, although voice intelligibility varied from fair to good. The VHF downlink voice spectrum contained a very loud tone at about 2.4 kHz. This tone has been tentatively associated with the noise from the lunar module cabin fan. As shown in Figure 2-5, the tone was evident at different times and was observed on the VHF and S-band systems.

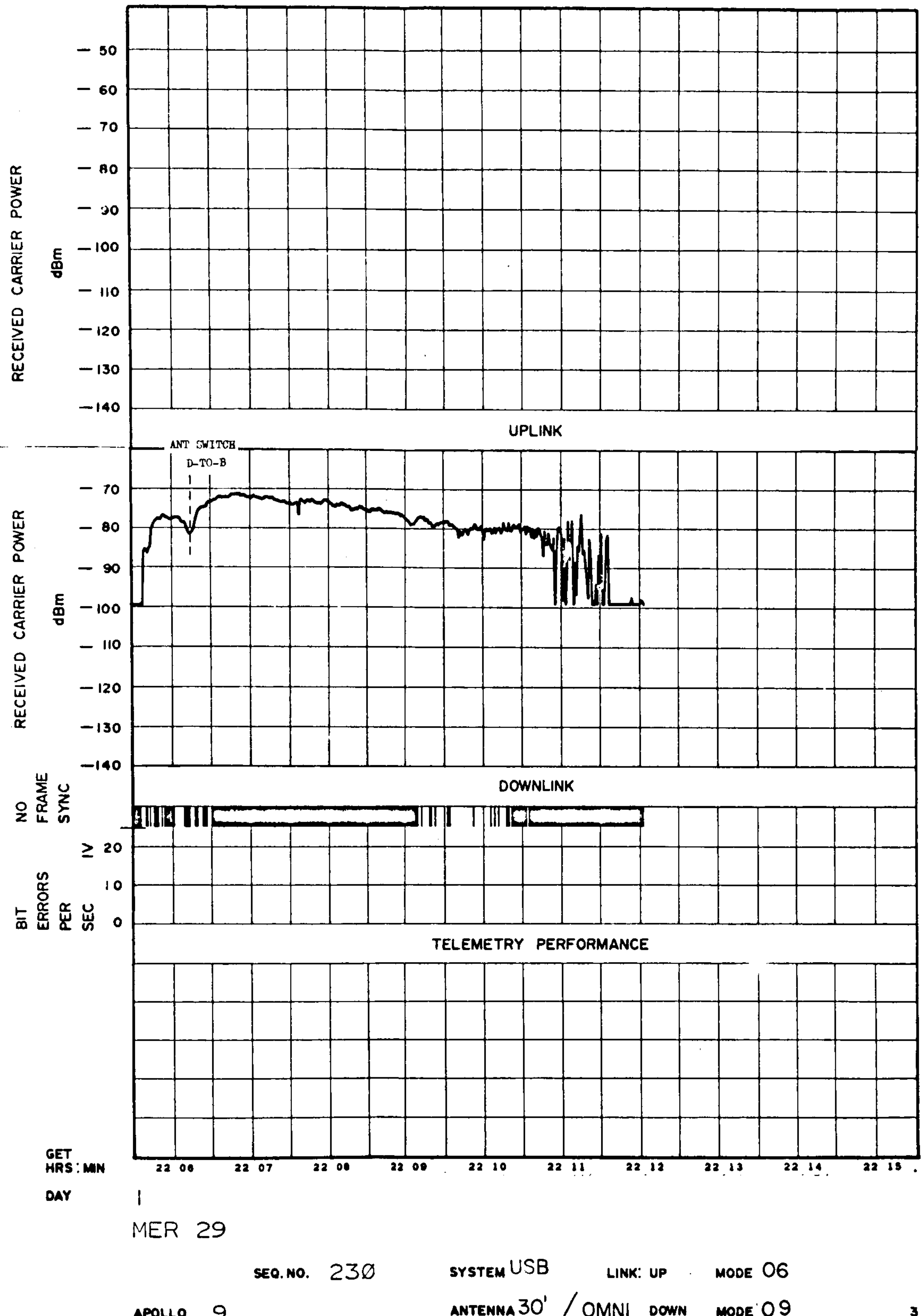
During the Honeysuckle track of the lunar module during revolution 29, the site reported difficulty with their autotracking, resulting in the antenna slewing off track. This resulted in sporadic side lobe tracking and false lock of the uplink and loss of signal during midpass. At re-acquisition, the lunar module downlink receiver locked to a spur for approximately 30 seconds. Approximately 1 1/2 minutes of lunar module telemetry data were lost as a result of the loss of signal and false downlink lock.



LM VOICE SPECTRUM

FIGURE 2-5

At Mercury during revolution 29, a lunar module/command and service module two-way relay check was performed successful after overcoming initial difficulty in adjusting the lunar module voice operated relay sensitivity. The site configuration message sent to the Mercury site indicated that the communications checks had been scrubbed and the lunar module would be in mode 6.02. Mercury acquired the lunar module in the phase modulation (PM) mode 6.02 with very weak and fluctuating downlink received carrier power. At approximately 046:04:16 the crew was advised to switch to downlink mode 10 (frequency modulation (FM)). At 046:05:07, the crew was requested to switch the lunar module S-band omni antenna from antenna 1 to antenna 2 because of the weak downlink carrier. As shown in Figure 2-6, at 046:05:40 the FM receiver automatic gain control (AGC) rose above threshold to approximately -80 dBm. Analysis of data indicated that the Mercury operators were not aware that the lunar module would switch from the phase modulation mode to the frequency modulation mode. The unexpected element in observing strange readings of the phase modulation receiver displays probably resulted in the station personnel failing to configure for FM mode operation with resultant loss of the telemetry. As shown in Figure 2-7, the received downlink carrier power level (approximately -80 dBm during the majority of the pass) is not compatible with the frame sync dropouts and frequent bit errors. The command and service module telemetry data observed during playback of the magnetic tape was extremely noisy and is probably not representative of the true real-time telemetry performance reported in Figures 2-6 and 2-7.



3

FIGURE 2-6 LM S-BAND FM COMMUNICATIONS PERFORMANCE DURING MER 29 PASS

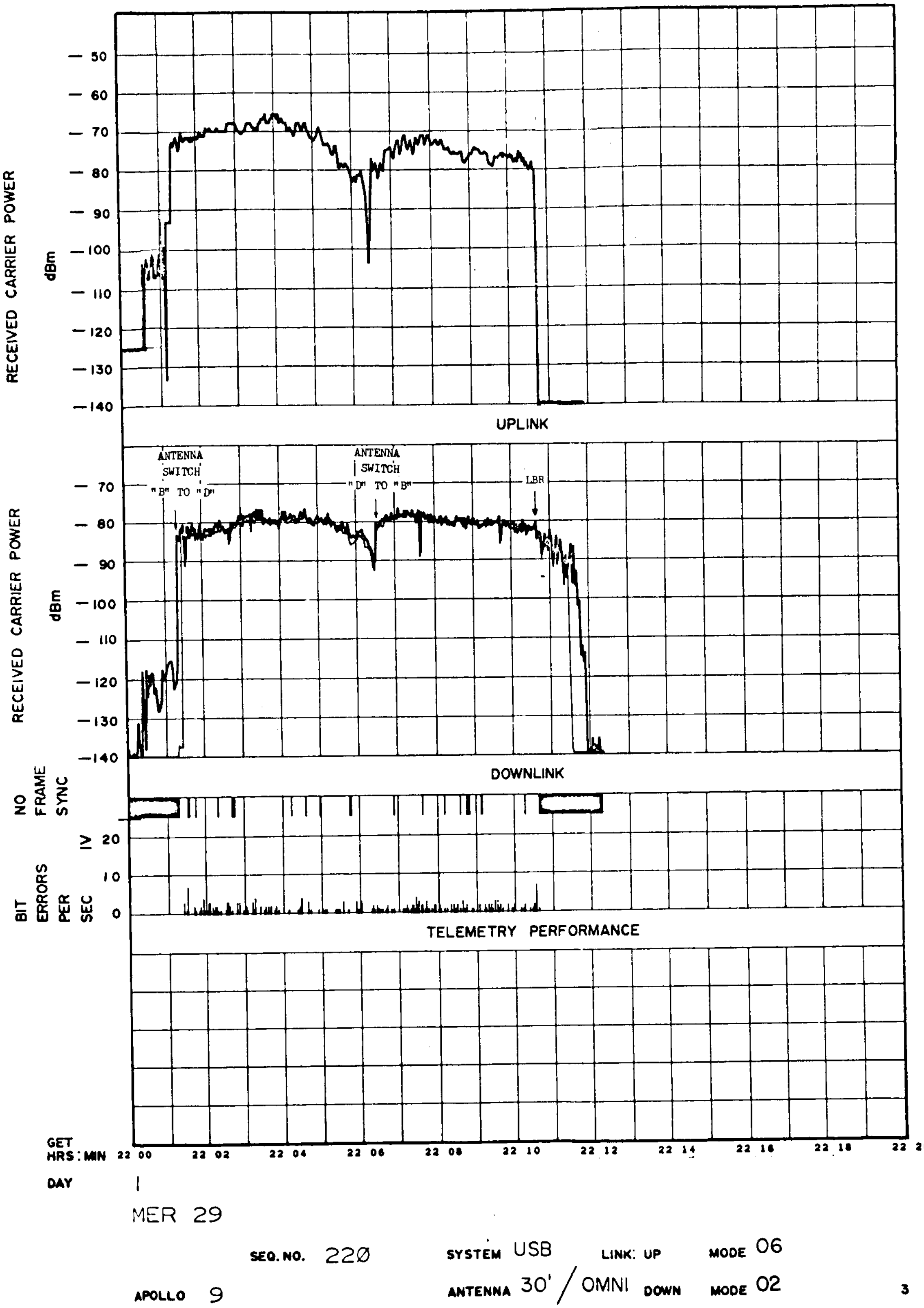


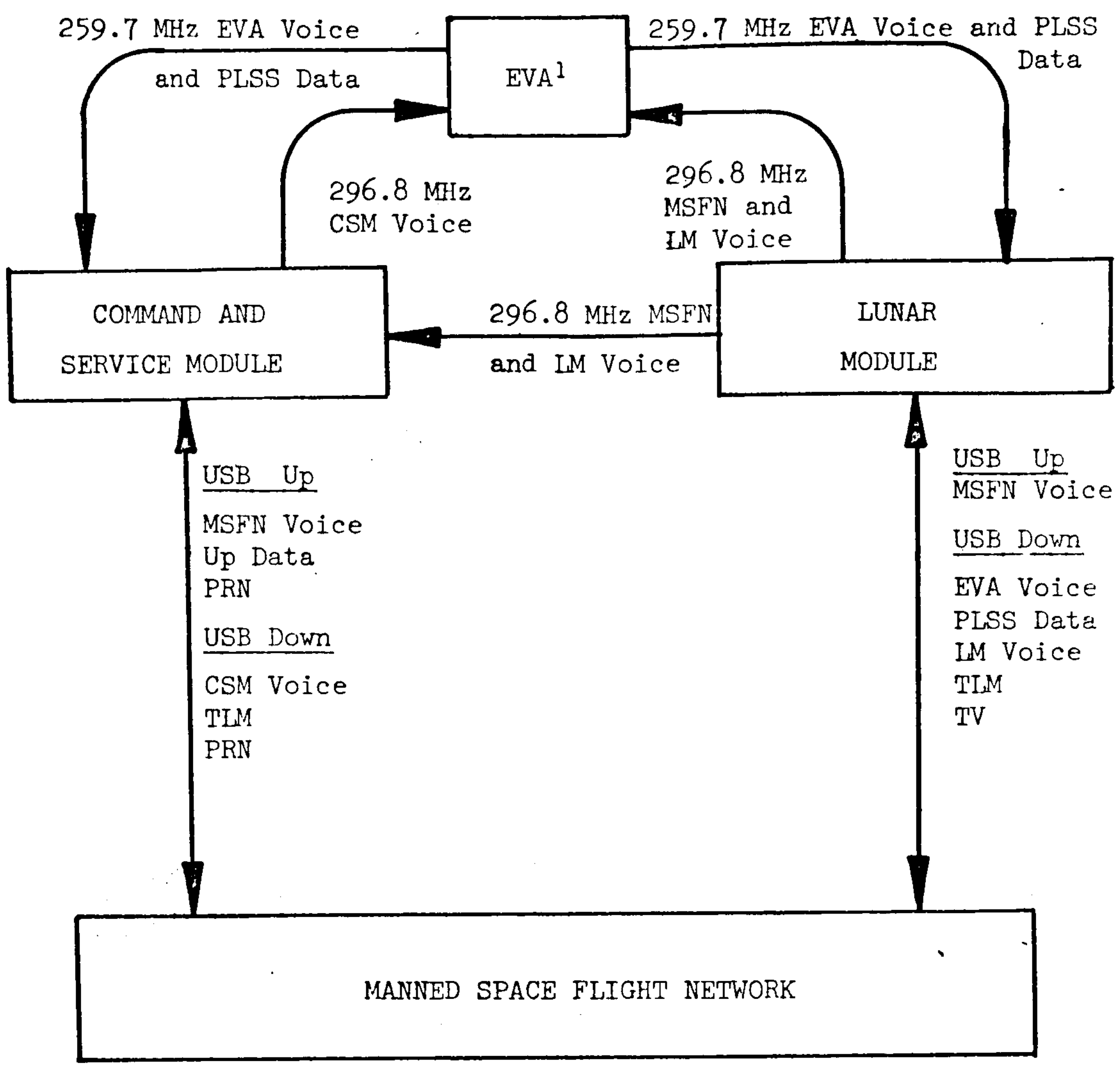
FIGURE 2-7 CSM S-BAND COMMUNICATIONS PERFORMANCE DURING MER PASS

A lunar module two-way relay check was accomplished at Texas during revolution 29. The communications configuration is presented in Figure 2-8. The background noise during voice transmission contains nonstationary tones that were 30 dBm below voice level. The nonstationary tones did not affect intelligibility. Voice quality was good during the check.

The portable life support system (PLSS) telemetry data from Texas revolution 29 was of excellent quality for the entire pass. The PLSS data agreed favorably with expected values. Battery voltage was about 16.2 Vdc and the electrocardiogram (EKG) wave **form** was good. There was less than one click per minute on the EKG wave form for over 95 percent of the pass. PLSS telemetry data from Merritt Island revolution 30 relayed through the command service module was generally good. The EKG waveform was good. Less than five clicks per minute was observed on the EKG data except for several intervals near acquisition, loss of signal, and during the Merritt Island keyhole. During these periods (about 10 percent of the pass) the EKG was unusable.

The Block II lunar module slow scan television performance was satisfactory. During the first transmission period, good quality television transmissions were received over Merritt Island on revolution 30. The signal-to-noise ratio averaged approximately 14 dB. Figures 2-9 and 2-10 present examples of television pictures and the corresponding slow scan video received at Merritt Island during revolution 30.

The lunar module S-band uplink voice was loud and clearly intelligible. S-band downlink voice from the lunar module prior to the television transmission was good, but during the television transmission,

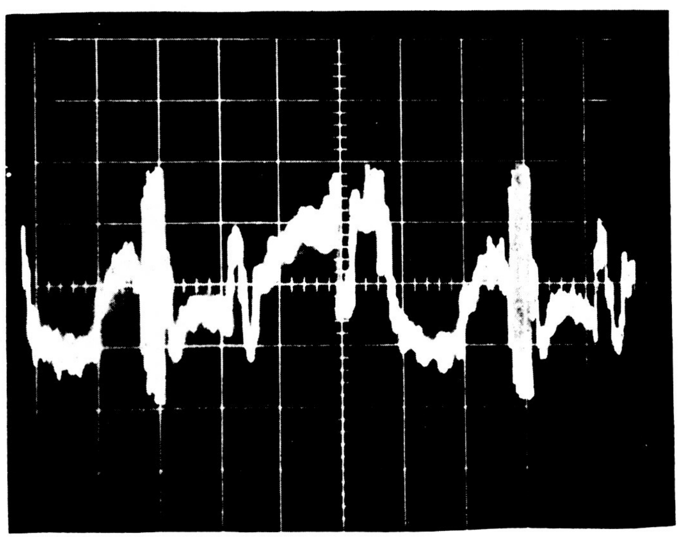


NOTES:

1. Check Accomplish with EVA in LM

FIGURE 2-8 COMMUNICATION CONFIGURATION - LM TWO-WAY RELAY (PLSS CHECKOUT)

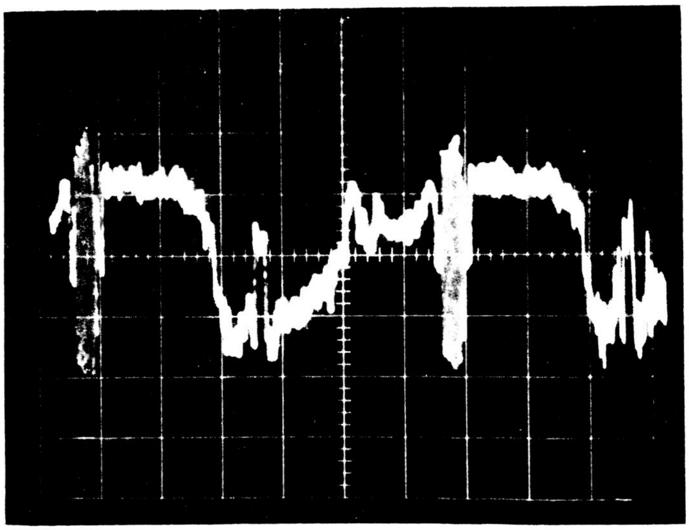
TELEVISION



TV VIDEO

FIGURE 2-9 LM TELEVISION, MIL REVOLUTION 30

TELEVISION

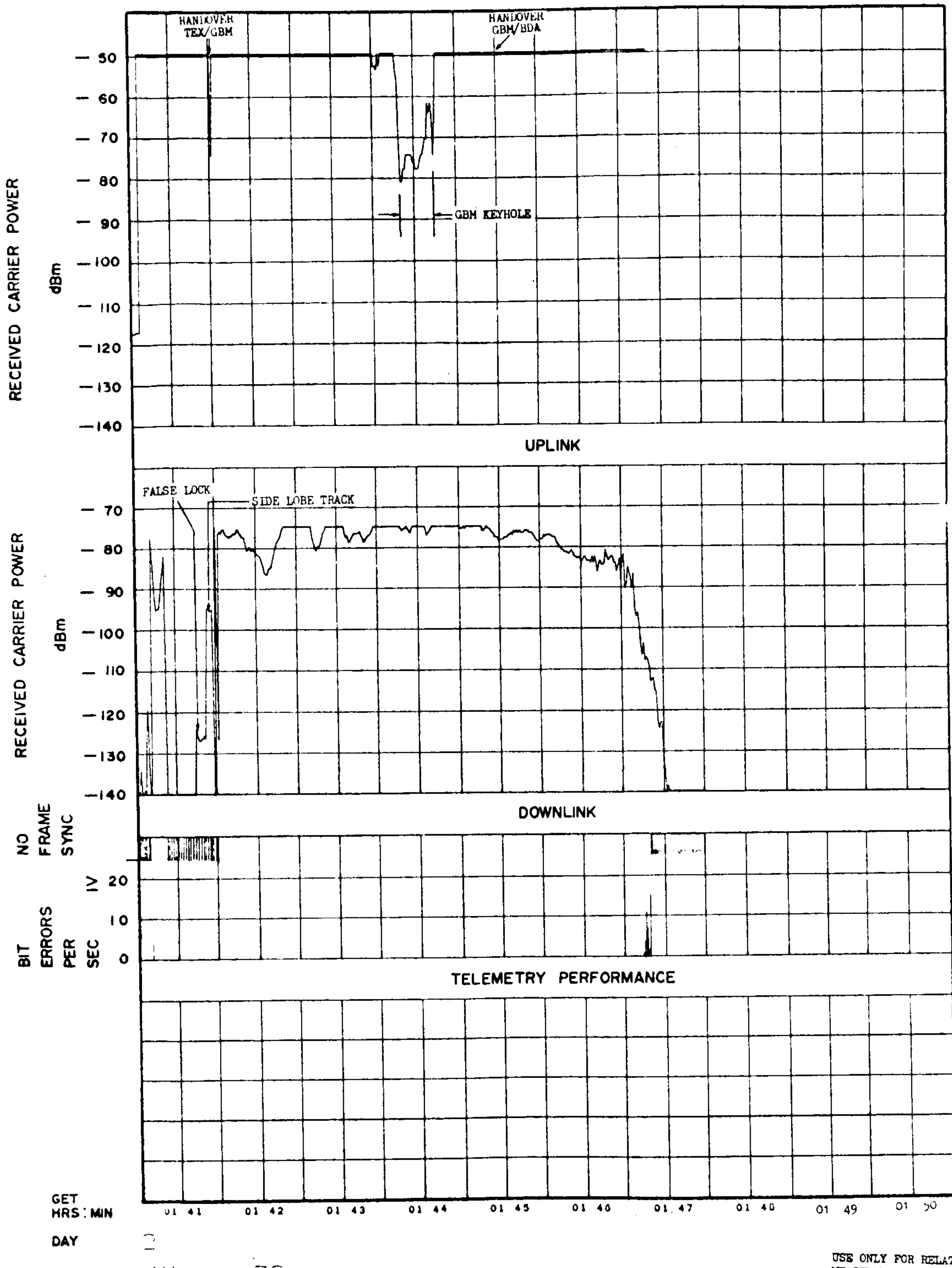


TV VIDEO

FIGURE 2-10 LM TELEVISION, MIL REVOLUTION 30 no lunar module S-band voice was remoted to Mission Control Center. The site received good lunar module unified S-band downvoice, but did not remote it to Houston. Refer to section 3.3 for additional detail. S-band downlink voice from the command/service module was good, and voice from the extravehicular activity astronaut while in the lunar module was of good quality. The Merritt Island site acquired the signal and two-way lock of the command and service module S-band at 046:27:03. The command and service module ranging acquisition was nominal and completed at 046:27:28, but the telemetry did not indicate decommutator lock until 046:28:12. From approximately 046:29:30 until 046:30:00, the uplink and downlink received carrier power levels dropped approximately 25 to 30 dB. At 046:33:40, Merritt Island handed over to Bermuda Island with no apparent loss of downlink, but approximately one-second uplink loss was observed. Merritt Island loss of signal of the command and service module S-band occurred at 046:34:06.

Merritt Island first acquired the lunar module FM downlink at approximately 046:27:45. At 046:29:50 the downlink FM signal fluctuated between -100 dBm and -85 dBm at which time the signal level stabilized to levels between -85 to -90 dBm. Loss of signal of the lunar module FM downlink occurred at 046:33:39.

As shown in Figure 2-11, the Merritt Island revolution 32 passive downlink coverage indicated good communications system performance during the descent propulsion system burn. Merritt Island experienced minimal difficulty near acquisition of signal and during the Texas to Grand Bahama Island handover. Merritt Island reported they were on program track throughout this pass due to failure of their Y-axis autotrack servo loop. As shown in Figure 2-12, during the Bermuda Island revolution 32 coverage, the uplink and downlink S-band received carrier power levels and telemetry performance were excellent during the descent propulsion system burn and throughout the pass.

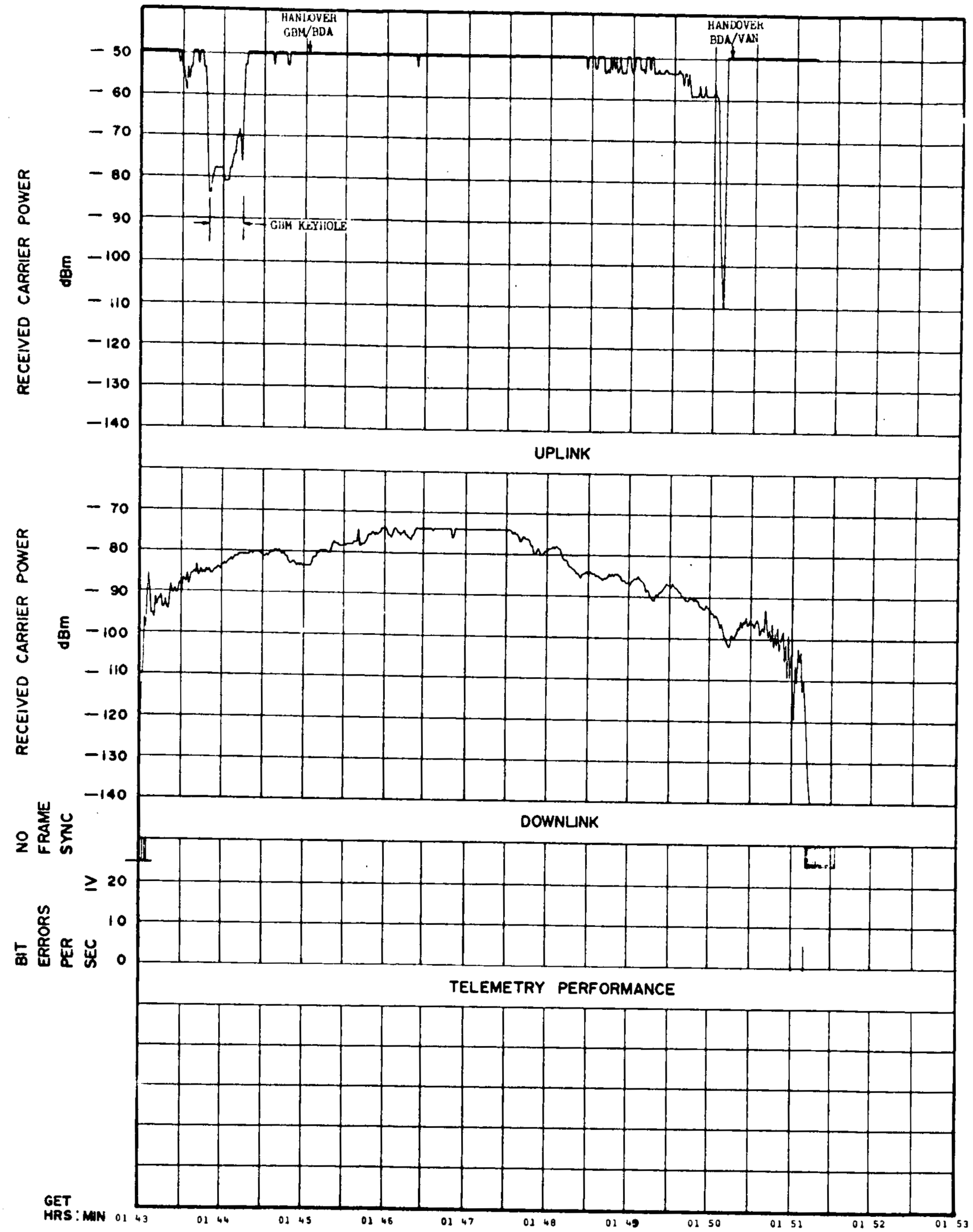


USE ONLY FOR RELATIVE MEASUREMENTS-CALIBRATION DATA IS INACCURATE

SEQ. NO. 353 SYSTEM USB LINK: UP MODE PASSIVE

APOLLO 9 ANTENNA 30' / OMNI DOWN MODE 02 3

FIGURE 2-11 LM S-BAND COMMUNICATIONS PERFORMANCE DURING THE DPS BURN



DAY 2

BDA 32

SEQ. NO. 330 SYSTEM USB LINK: UP MODE 06

APOLLO 9 ANTENNA 30' / OMNI DOWN MODE 02

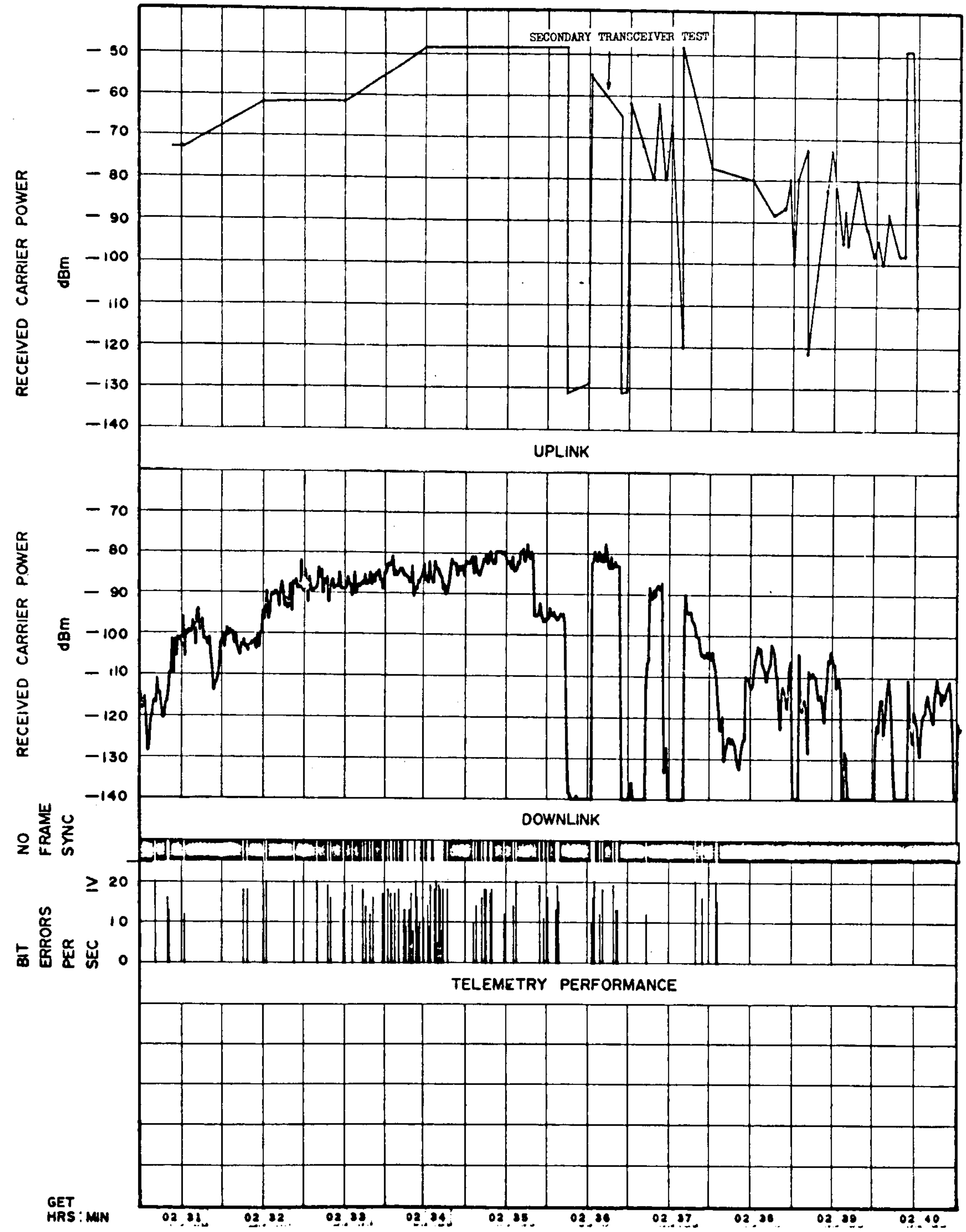
3

FIGURE 2-12 LM S-BAND COMMUNICATIONS PERFORMANCE DURING THE DPS BURN

During the Carnarvon revolution 32 pass, a series of communications mode checks were accomplished. Figure 2-13 shows the S-band uplink and downlink received carrier power levels and telemetry data as observed from the station magnetic tape recording were extremely noisy and appeared to have a continuous error in one of the words. The error resulted in nearly continuous loss of frame sync. From acquisition of signal until 050:35:40, the lunar module was on primary transceiver. Switching to secondary transceiver resulted in an approximately 20 second loss of signal. Between 050:36:03 and 050:36:45, backup downlink voice was observed as carrier suppression during the secondary transceiver operation.

After this time, frequent switching between modes (hi power and feed thru-power amplifier off and on) caused loss of downlink lock. Good ranging acquisition was apparent during the early portion of the pass while on primary transceiver. The extremely short time allocated to any one communications mode check severely limited the quality and confidence in the interpretation of the available data, although the communication system probably functioned properly. In addition, the rapidity of the crew switching violates the written detailed test objectives. The crew should adhere to the specified data times to insure that there are sufficient data available for operations analysis.

VHF simplex B operation over Carnarvon during revolution 32 appeared normal. The noise level increased in amplitude due to apparent cabin fan noise within the lunar module. This caused voice quality to be poor and intelligibility to be fair. The frequency of the fan motor noise was about 2.4 kHz.



DAY 2

CRO 32

SEQ. NO. 290 SYSTEM USB LINK: UP MODE

APOLLO 9 ANTENNA 30' / OMNI DOWN MODE 3

FIGURE 2-13 LM S-BAND COMMUNICATIONS PERFORMANCE DURING COMMUNICATIONS MODE CHECKS

The capsule communicator requested a secondary S-band check at 50:34:42 and also requested Carnarvon to remote S-band to Mission Control Center at 50:35:30. Step 1 (power amp-off), step 2 (power amp-secondary), and step 3 (transceiver-secondary) were accomplished and voice was good. Then the capsule communication requested the crew to do an S-band down voice backup check (50:36:43), but failed to tell the Carnarvon stations to remote S-band backup voice. Carnarvon voice tapes and telemetry magnetic tapes do not have backup voice recorded. Therefore, it is suspected that in actuality VHF was remoted to Mission Control Center. During the secondary S-band check, speech quality was fair and intelligibility was good. However, on the backup downvoice check, the voice gain adjusting amplifier (VOGAA) popping could be heard on recordings that were analyzed. Carnarvon further confirmed that no backup downvoice was heard at the station since the check occurred during predicted station loss of signal.

A lunar module backup voice check was conducted over Honeysuckle on revolution 32. The voice received in Mission Control Center was very weak during this check. Honeysuckle did record the backup voice, but analysis of this data shows that voice received at the station was weak and of poor quality and of only fair intelligibility.

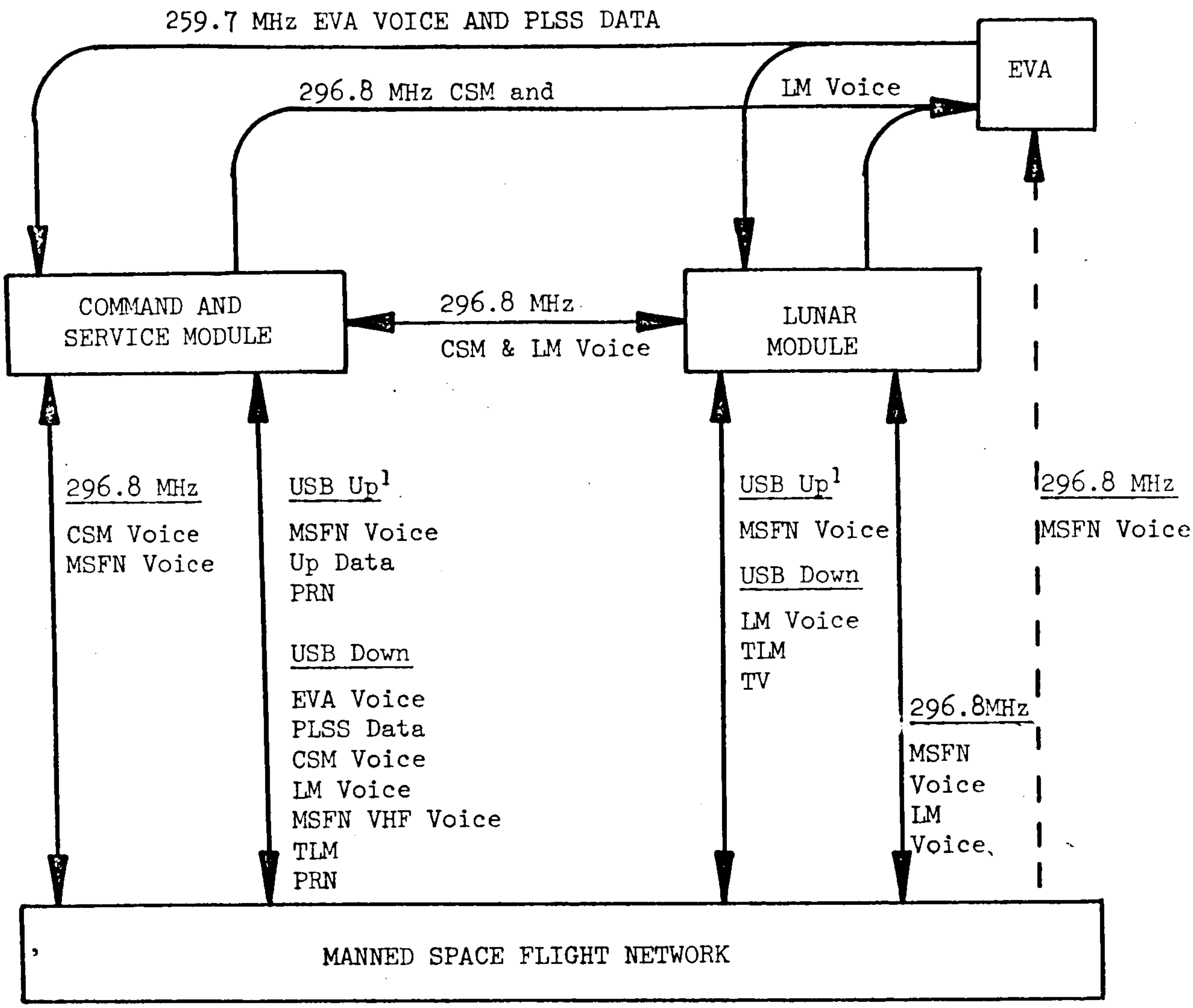
2.4 Extravehicular Activity Period

Excellent quality voice transmissions were received from each of the crewmen during the extravehicular activity. However, the crew did not receive the capsule communicator transmissions through the Texas, Merritt Island, Bermuda Island, and Vanguard sites. One of the capsule communication transmissions through the Guaymas site was received by the crew. Improper configurations at these sites resulted in all voice transmissions except one being on the S-band uplink only. Spacecraft reception of the S-band transmissions was inhibited by the spacecraft volume control settings (full decrease). Voice transmissions through Bermuda Island occurred during periods of intervehicular communications when the spacecraft VHF receivers were captured. Good quality uplink voice was received by each of the crewman during transmissions through the Huntsville, Redstone, and Canary Island sites. The command and service module one-way relay configuration used throughout the extravehicular activity is presented in Figure 2-14. In this configuration, the crew communicates via VHF with the command and service module relaying to the MSFN via the S-band.

Satisfactory portable life support system telemetry performance was observed during the extravehicular activity. An evaluation of portable life support system telemetry data over Bermuda Island on revolution 47 indicated that the portable life support system data were good except during periods when S-band downlink was near threshold. This was due to a drop in signal strength during Merritt Island/Bermuda Island handover and Bermuda Island tracking with lock through their keyhole. Evaluation of this data indicates that it was not affected by the lunar module simplex A VHF transmissions. Intelligibility of the voice from the extravehicular astronaut was good during this pass.

2.5 Rendezvous

During revolution 59, Antigua provided coverage of the command and service module/lunar module undocking. Antigua acquired two-way lock with the command and service module at 092:36:50 and passive acquisition of signal of the lunar module at 092:38:10. From acquisition of the command and service module until an omni switch at 092:39:30, the signal levels fluctuated between -90 dBm and -120 dBm. The lunar module downlink received carrier power levels were steady at approximately -74 dBm during this period. The undocking occurred at 092:38:41 and there was no evidence of change in carrier power levels related to the



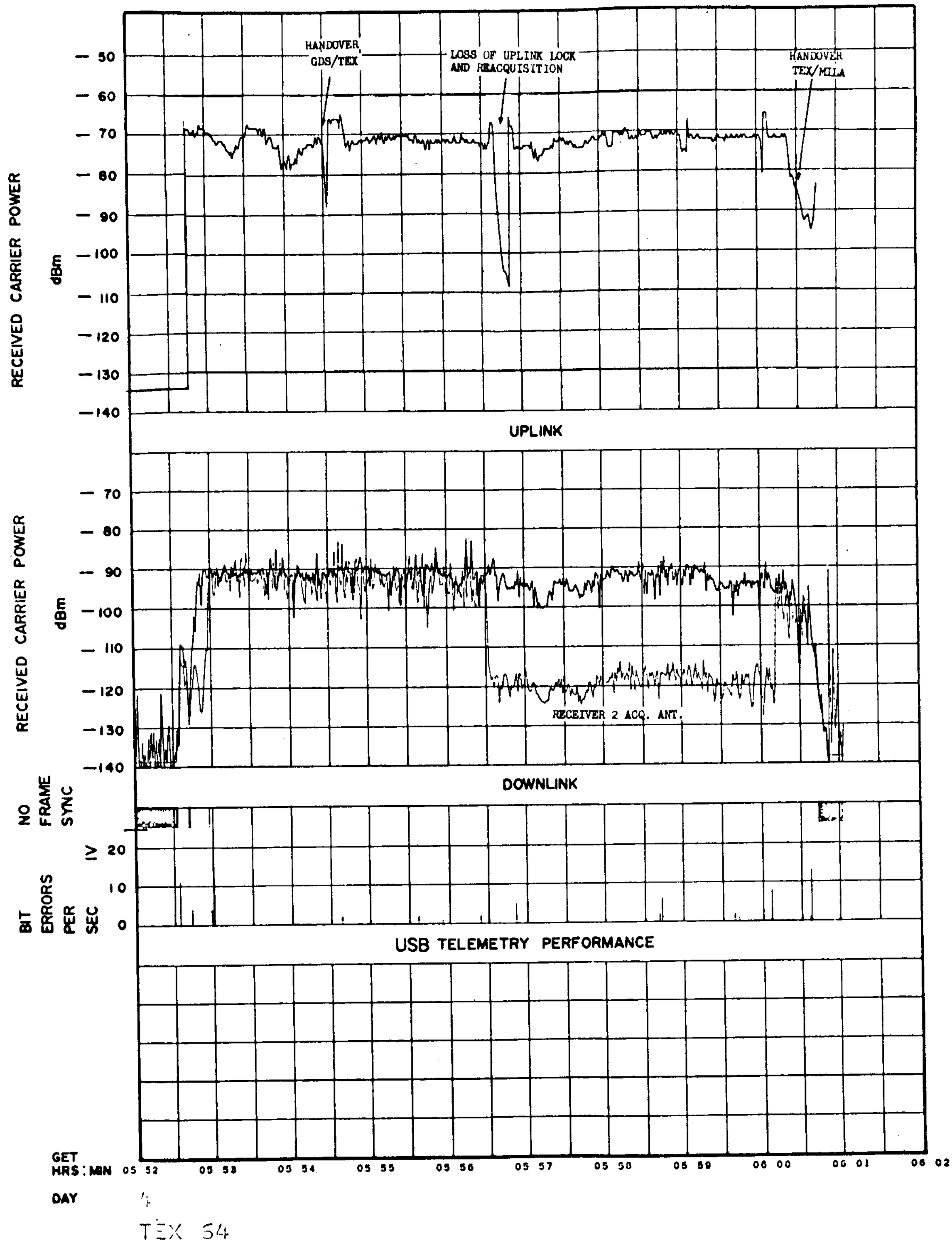
NOTES:

1. S-Band Volume Turned Down

FIGURE 2-14 PRIMARY COMMUNICATIONS CONFIGURATION - EXTRAVEHICULAR ACTIVITY (CSM ONE-WAY RELAY) undocking maneuver for either vehicle. A 10-second loss of signal of the command and service module downlink and a one-second loss of signal of the lunar module downlink was observed during the handover from Antigua to Vanguard. The lunar module data available for evaluation was limited, but indicated satisfactory RF, telemetry, and ranging performance.

Figure 2-15 is a presentation of the S-band performance during Texas revolution 64 coverage of the ascent propulsion system burn to depletion. The RF and telemetry performance was generally good. Texas experienced an approximate 15 second loss of uplink during the burn; however, there is no apparent degradation of the RF downlink or telemetry performance associated with this occurrance. Texas reported ranging difficulty during this pass and attributed the ranging problem to improper adjustment of the pseudorandom noise ranging modulation index for uplink signal combination 01. Further lunar module ranging problems are discussed in Section 3.5.

Figure 2-16 is a composite presentation of the Merritt Island revolution 65 S-band and VHF telemetry performance in addition to S-band uplink and downlink received carrier powers. The abrupt loss of S-band telemetry at 101:59:40 appears to be a site recording or patching configuration problem and unrelated to the S-band RF downlink or spacecraft equipment. As shown on the revolution 64 plot (Figure 2-14), Texas had good S-band telemetry until loss of signal at 102:00:40. The VHF telemetry appeared to be of good to excellent quality throughout the pass. The site strip chart data indicated that Merritt Island was unable to acquire ranging during their active uplink coverage. The Merritt Island postlaunch instrumentation messages data sheet reports apparent false lock on the uplink after reacquisition from keyhole exit until 102:02:00, when Merritt Island dropped the uplink and reacquired at 102:02:20.



SEQ. NO. 133 SYSTEM USB LINK: UP MODE 01

APOLLO 9 ANTENNA 30' / OMNI DOWN MODE 02 3

FIGURE 2-15 LM S-BAND COMMUNICATIONS PERFORMANCE DURING APS BURN TO DEPLETION

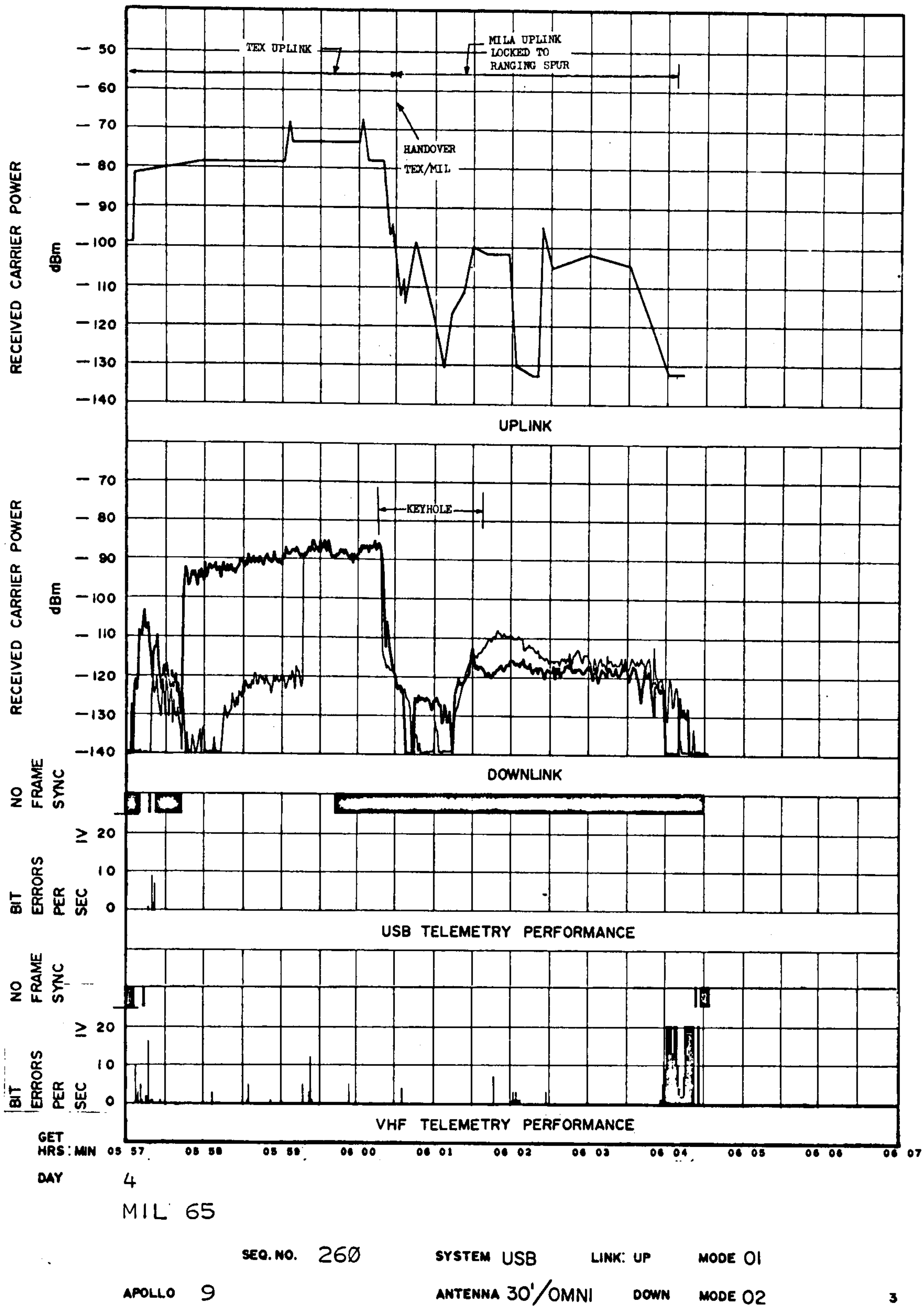


FIGURE 2-16 LM S-BAND COMMUNICATIONS PERFORMANCE DURING THE APS BURN TO DEPLETION

2.6 Command Module Operations (Post Lunar Module)

During the post lunar module period, several command and service module telecommunications checks were performed. A major problem in the unified S-band command system prevented proper uplink command operation from 108:43:03 to 118:46:53. This is discussed in detail in Section 3.6.

Real-time checks were performed to determine the cause of tones present in the data storage equipment dumped voice. The narrow band TR-104 ground receivers were isolated as being the cause of these tones. This special investigation is discussed in Section 3.6.

A high gain antenna check was added to the Apollo 9 flight plan and accomplished over Carnarvon and Hawaii during revolution 122. Prior to acquisition of signal at Carnarvon on revolution 122, the spacecraft attitude was set so that the signal would be lost before scan limits were reached. This was done to determine if the antenna would slew (when the AGC decays) far enough to hit the scan limits to simulate the spacecraft going behind the moon. To simulate the high gain antenna operation during crew sleep periods when passive thermal control was being used, the high gain antenna was set up to be driven into scan limits when Hawaii revolution 122 acquisition of signal occurred. Preset look angles were set into the high gain antenna electronics to determine if the high gain antenna would automatically re-acquire.

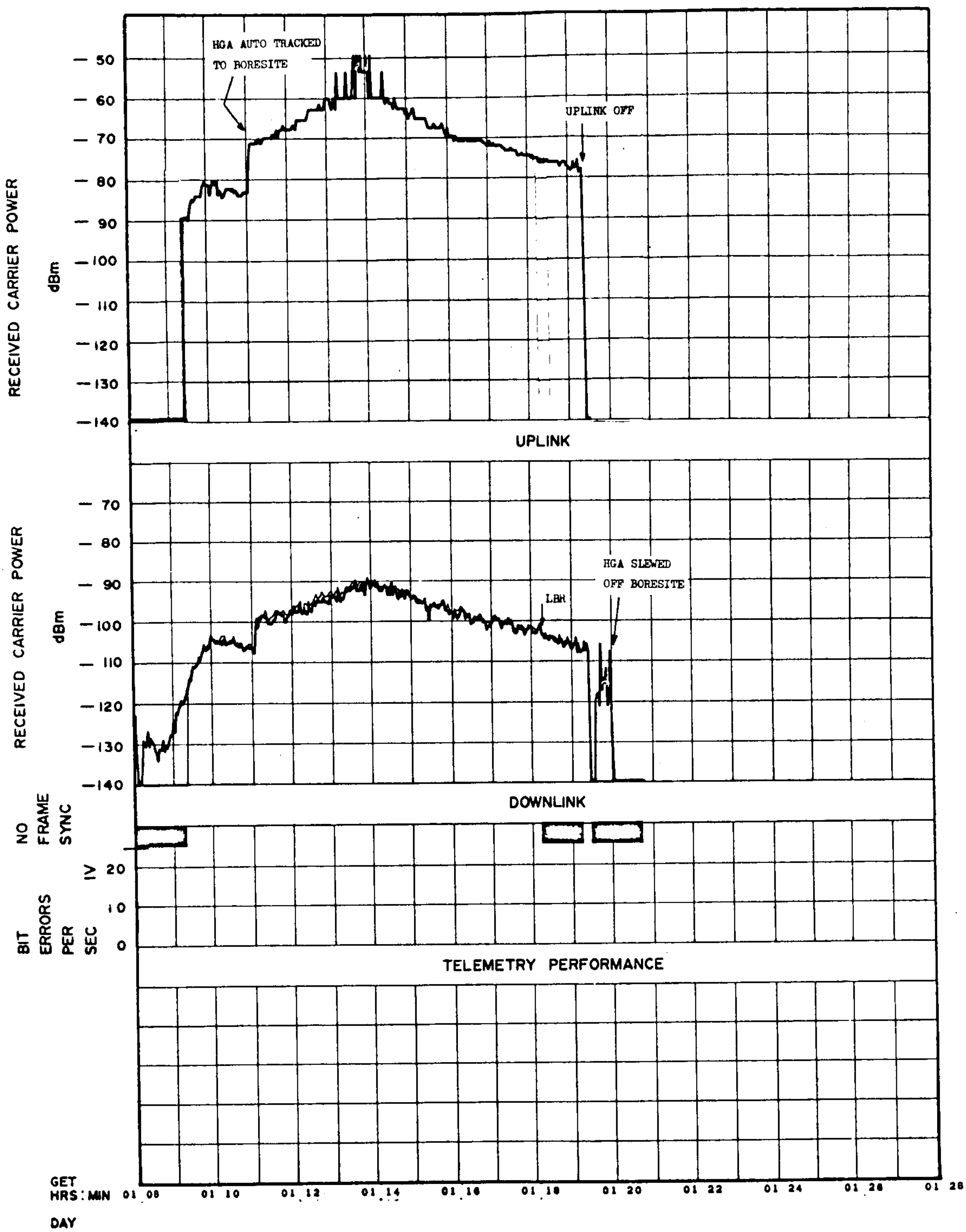
Carnarvon acquired the command and service module at a range of approximately 1100 nautical miles (based on premission trajectory data). The predicted look angles for pitch and yaw were pre-set and the high gain antenna was in wide beamwidth. Carnarvon data indicated that the site was configured for an uplink power output of approximately 350 watts. The spacecraft was configured for downlink transmission in the bypass mode.

As shown in Figure 2-17, Carnarvon acquired the spacecraft at 193:08:12 at a received downlink carrier power of -136 dBm. At approximately 1000 nautical miles, the telemetry was switched from low bit rate to high bit rate. The received uplink carrier power at this time was -99 dBm with a received downlink carrier power of -121 dBm. These RF levels agreed with predictions to within 1 to 2 dB.

At 193:11:05, the high gain antenna was switched to autotrack and immediately tracked to boresite, showing an improvement of approximately 11 dBm in both uplink and downlink received carrier power. At the point of closest approach the slant range was approximately 270 nautical miles (based on premission trajectory predictions). The uplink received carrier power was -64 dBm and the downlink received carrier power was -86 dBm at this point. These carrier power levels agreed very favorably with predictions.

At 193:18:14, the telemetry was switched from the high to the low bit rate. AT 193:19:24, the high gain antenna slewed off boresight when Carnarvon terminated uplink transmissions. This resulted in downlink loss of signal for Carnarvon. The uplink and downlink carrier power levels just prior to this slewing were -80 dBm and -107 dBm respectively. The termination of the uplink resulted in the spacecraft transponder switching to auxilliary oscillator. Carnarvon re-acquired downlink lock at 193:13:31 with a downlink received carrier power of -113 dBm. Normal loss of signal of the downlink carrier occurred at 193:19:57 when the downlink carrier power reached -135 dBm. The data does not indicate any appreciable change of high gain antenna pitch and yaw look angles during these events.

The Hawaii pass was a continuation of the high gain antenna reacquisition mode check. Figure 2-18 presents the coverage during this pass. The Hawaii site and the spacecraft communications configuration were



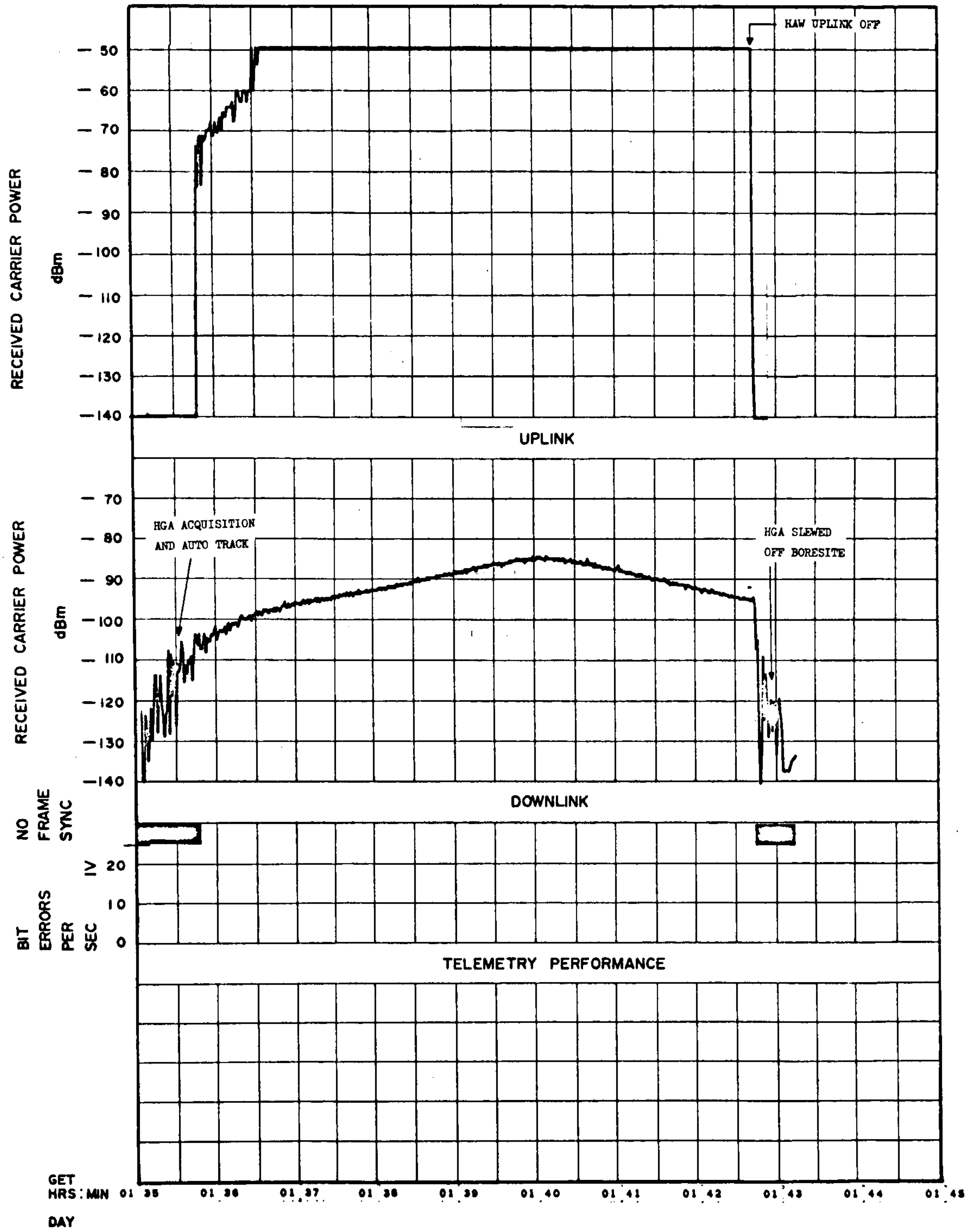
CRO 122

SEQ. NO. 21Ø SYSTEM USB LINK: UP MODE 06

APOLLO 9 ANTENNA 30' DOWN MODE 02

AND HIGH GAIN ANTENNA (CSM)

FIGURE 2-17 CSM S-BAND HIGH GAIN ANTENNA CHECK
DURING CRO 122 PASS 2-32



HAW 122

SEQ. NO. 1 Ø SYSTEM USB LINK: UP MODE 06

APOLLO 9 ANTENNA 30' DOWN MODE 02 3

AND HIGH GAIN ANTENNA (CSM)

FIGURE 2-18 CSM S-BAND HIGH GAIN ANTENNA CHECK DURING HAW 122 PASS 2-33 the same as that for Carnarvon on revolution 122. Hawaii S-band uplink transmitter power was approximately 350 watts and the spacecraft transponder was in the bypass mode.

The spacecraft attitude and the high gain antenna pitch and yaw angles were such that at acquisition of signal the high gain antenna (wide beam mode) immediately locked to the Hawaii uplink carrier and autotracked smoothly throughout the pass. The uplink and downlink received carrier power levels agreed favorably with calculations for antenna gains, transmitter power levels, and premission predicted trajectory data. When Hawaii terminated the uplink, the transponder switched to the auxilliary oscillator causing a momentary loss of downlink lock. The high gain antenna slewed off boresight several degrees as expected. Telemetry performance was very good during the pass.

2.7 Reentry

Command module communications performance during reentry was nominal. After the black-out period, satisfactory voice communications were again established.

3.0 SPECIAL INVESTIGATION

The following special investigations represent major discrepancies occurring during Apollo 9 or areas of special interest that were identified as needing further testing or evaluation.

3.1 Merritt Island Telemetry Investigation

In response to a request from the Apollo Spacecraft Program Office, a special investigation was conducted of the Merritt Island telemetry performance during revolutions 1, 15, and 17. This request stated that the telemetry during these passes was as follows:

	PERCENT OF PASS WITH REPORTED TELEMETRY	QUALITY
REV 1	88%	Good Telemetry
REV 15	81%	Good Telemetry
REV 17	98%	Good Telemetry

The following is an analysis of the unified S-band radio frequency performance for the passes.

Revolution 1

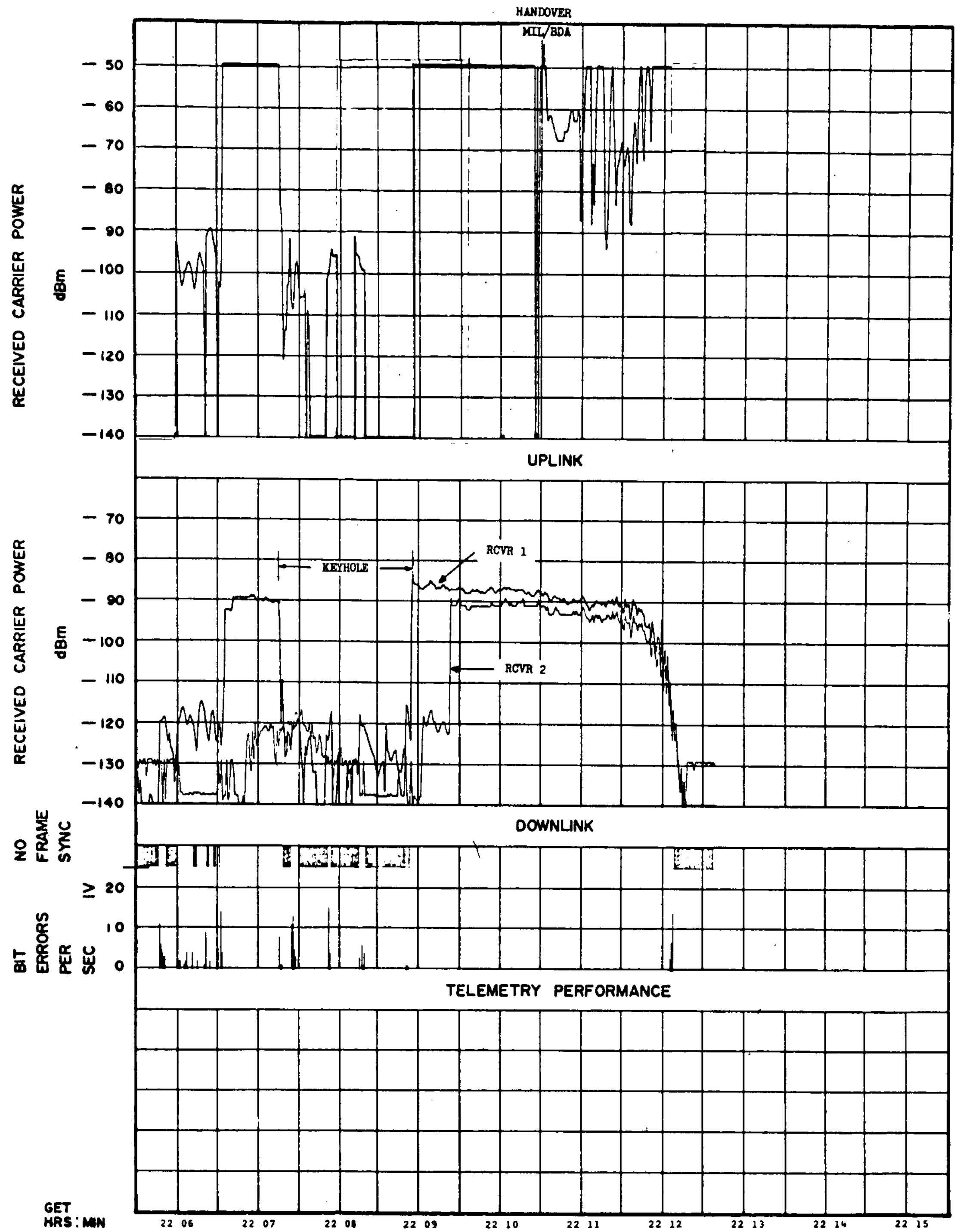
The launch coverage and the causes for loss of telemetry are explained in Section 2.1. As shown in Figure 2-2 telemetry performance correlated well with the downlink received carrier power. The station at Merritt Island observed the S-band downlink for about 555 seconds. During this time telemetry data was received for about 440 seconds or 80% of the pass.

Revolution 15

Figure 3-1 presents the S-band uplink and downlink received carrier power levels and the high bit rate telemetry performance. The downlink received carrier power levels shown are in error by approximately -6 dBm due to inaccurate calibration data from the site wideband recorder tape. The carrier power levels (when corrected by +6 dBm factor based on strip chart data) agree with the telemetry performance presented on the plot. Merritt Island acquired on a side lobe then went to main lobe for a short period of time and finally entered keyhole. Good downlink carrier power levels were maintained during the balance of the pass until normal loss of signal. The Merritt Island station had a total pass coverage of approximately 390 seconds of which good telemetry was observed for 290 seconds (approximately 75 percent) based upon the Information Systems Division laboratory analysis. As shown in Figure 3-1, the received telemetry is consistent with the downlink received carrier power. The downlink received carrier power was sufficient to sustain telemetry for about 75 percent of the pass.

Revolution 17

Figure 3-2 presents the S-band radio frequency uplink and downlink received carrier power levels and telemetry performance of the command and service module. With the exception of the handover from Texas to Merritt Island and the Merritt Island to Bermuda Island handover, the downlink received carrier power level was adequate to support good high bit rate telemetry performance between acquisition and loss of signal. The downlink received carrier power levels shown are in error by approximately -6 to -10 dB; therefore, the -95 dBm level shown during the period from 025:15:00 to 025:17:00 is in reality approximately -85 to -89 dBm. These errors are due to poor calibration on the station wideband recorder magnetic tape. Of 460 seconds coverage, only 10 to 12 seconds of telemetry data were lost, which provided



DAY

MIL 15

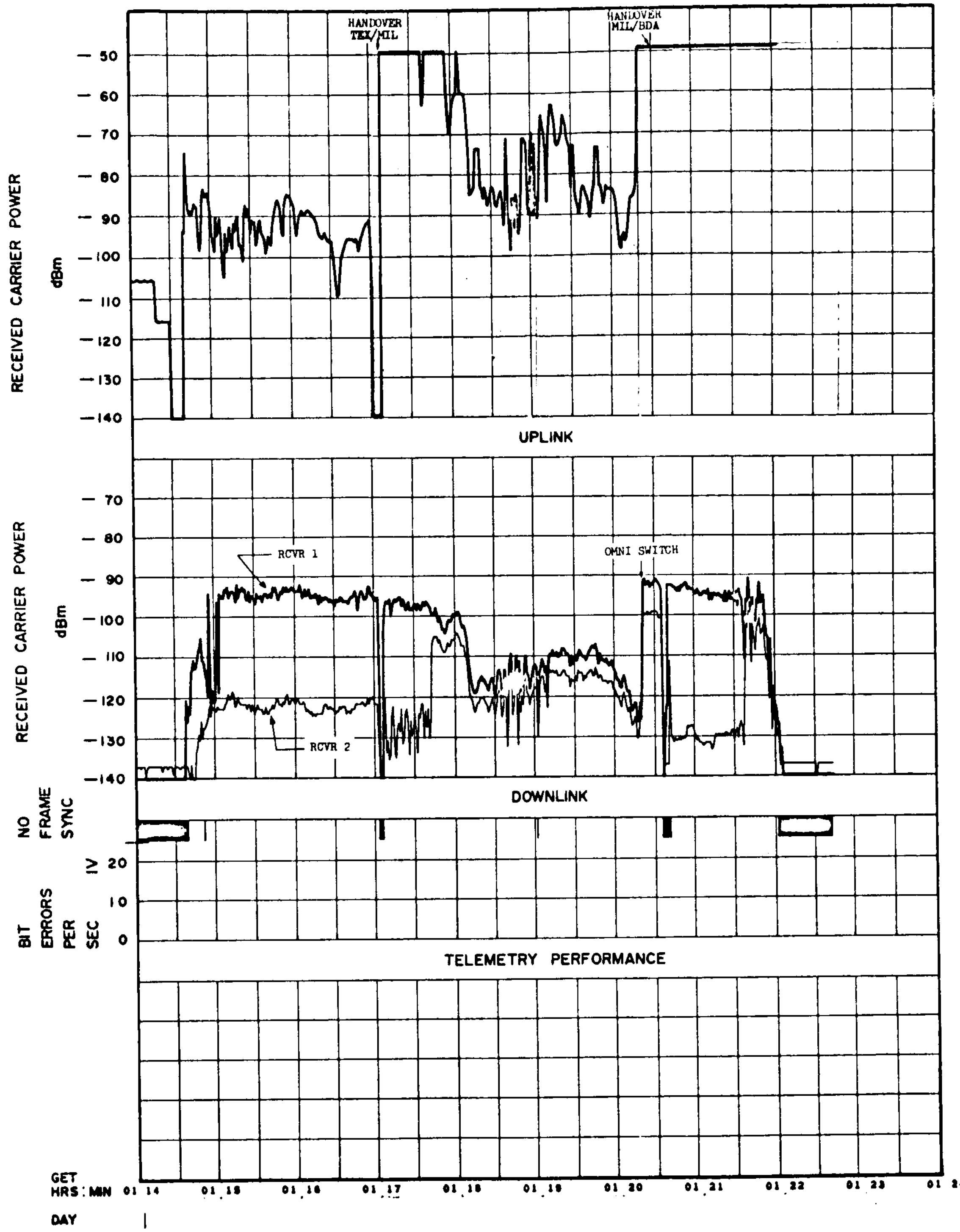
HIGH BIT RATE TELEMETRY

SEQ. NO. SYSTEM USB LINK: UP MODE 06

APOLLO ANTENNA 30'/OMNI DOWN MODE 02

3

FIGURE 3-1 CSM S-BAND COMMUNICATIONS PERFORMANCE DURING MIL 15 PASS



MIL 17

USE ONLY FOR RELATIVE MEASUREMENTS-CALIBRATION DATA IS INACCURATE

SEQ. NO. 18Ø SYSTEM USB LINK: UP MODE 06

APOLLO 9 ANTENNA 30' / OMNI DOWN MODE 02

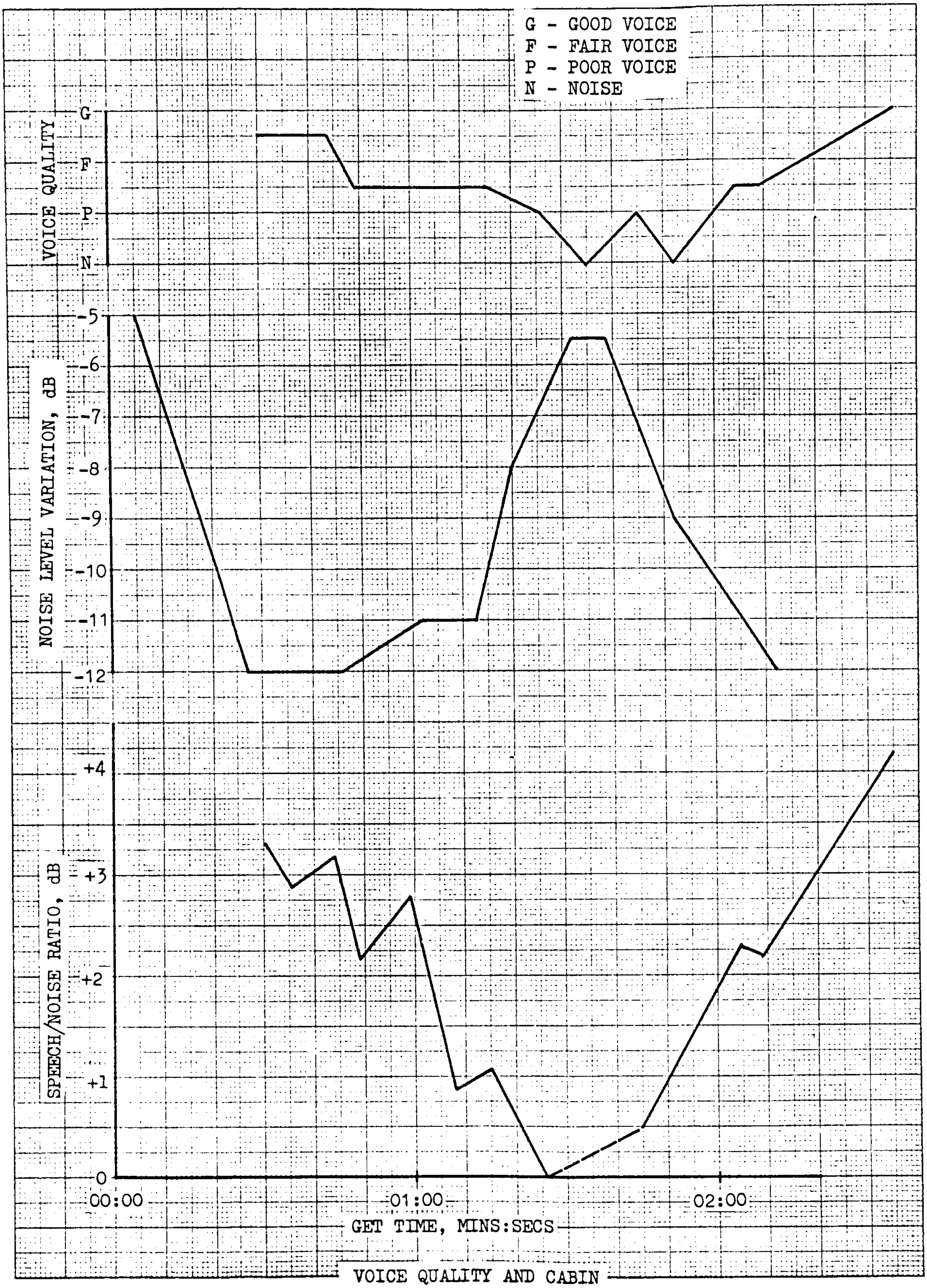
FIGURE 3-2 CSM S-BAND COMMUNICATIONS PERFORMANCE DURING THE MILA 17 PASS

98 percent telemetry performance. As shown in Figure 3-2, this is consistent with the downlink received carrier power.

3.2 Command And Service Module Launch Noise Evaluation

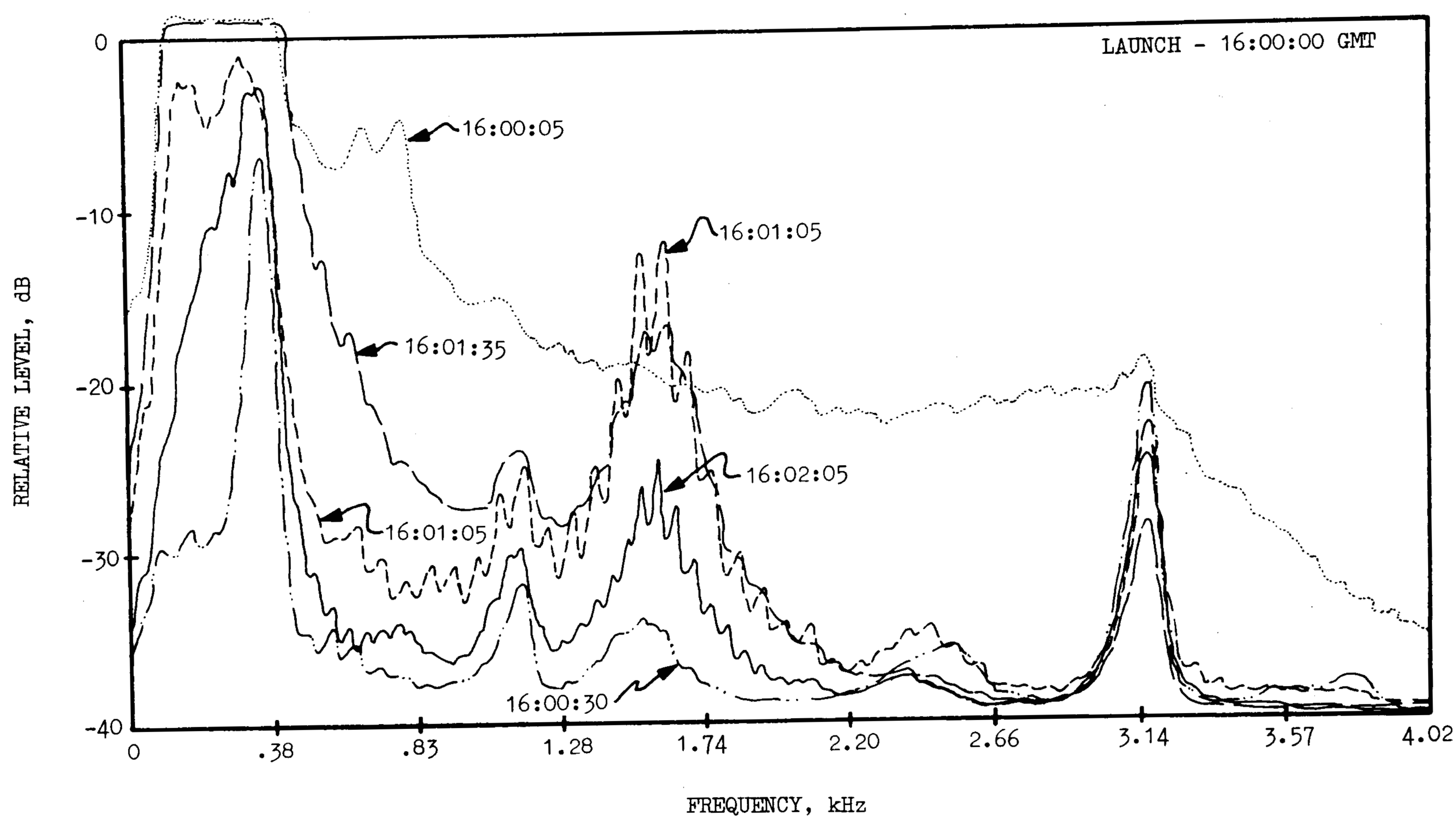
Because of high noise levels in the interior of the command and service module during the launch phase of the Apollo 8 mission, the command and service module data storage equipment was utilized to record crew conversation and noise at launch through the crew intercomm to determine to what degree cabin noise degraded voice communications.

The data storage equipment was dumped over Texas on revolution 1, and the data was analyzed to obtain speech quality information. Figure 3-3 presents a summary of this information. Three curves are plotted in this figure. Curve A is a plot of voice quality as recorded by the data storage equipment. As shown in this figure voice quality is very poor for a 25 second interval around maximum dynamic pressure. Curve B is a plot of the internal cabin noise recorded along with the voice. This curve shows that during maximum dynamic pressure the cabin noise is very high and is a major factor in lowering the voice quality. This is more clearly demonstrated in curve C which shows that during this same interval the speech-to-noise ratio goes to 0. Outside this interval the speech-to-noise ratio is above + 1 dB where the noise is lower providing better speech quality. Figure 3-4 shows the frequency variation of the speech and noise levels during the first two minutes of the mission. The data analyzed was from 000:00:00 to 000:03:05 GET.



VOICE QUALITY AND CABIN NOISE DURING LAUNCH.

FIGURE 3-3



DSE DUMP SPECTRUM - LAUNCH PHASE

FIGURE 3-4

3.3 VOGAA Laboratory Evaluation

During the first lunar module television transmission, no lunar module voice was received through the Merritt Island site during revolution 30. The pictures received during this transmission were of excellent quality, but S-band voice was not received at Mission Control Center because the Merritt Island site did not remote the voice. A possible cause of the remoting problem was that the voice gain adjusting amplifier (VOGAA) which was installed in the S-band downlink voice loop at Merritt Island may have inhibited the S-band voice. It was thought that the limiting of the voice may have been because of tone interference in the voice spectrum or low speech-to-noise ratios restricting the VOGAA operation.

To determine the normal operational conditions of this amplifier and to establish under what conditions it would inhibit voice at the output, a laboratory evaluation was conducted. This evaluation further provided data to allow a recommendation to be made as to whether this amplifier should be used during the Apollo 10 mission.

Figure 3-5a presents the VOGAA configuration at the ground station. The VOGAA is normally operated in the expansion mode with all settings at mid-range.

The VOGAA is a voice gain adjusting amplifier capable of attenuation and amplification. Its function is to limit unwanted stationary random or stationary periodic signals while enhancing the changes in amplitude (voltage excursions). The point at which enhancement will occur is determined by the mode switch.

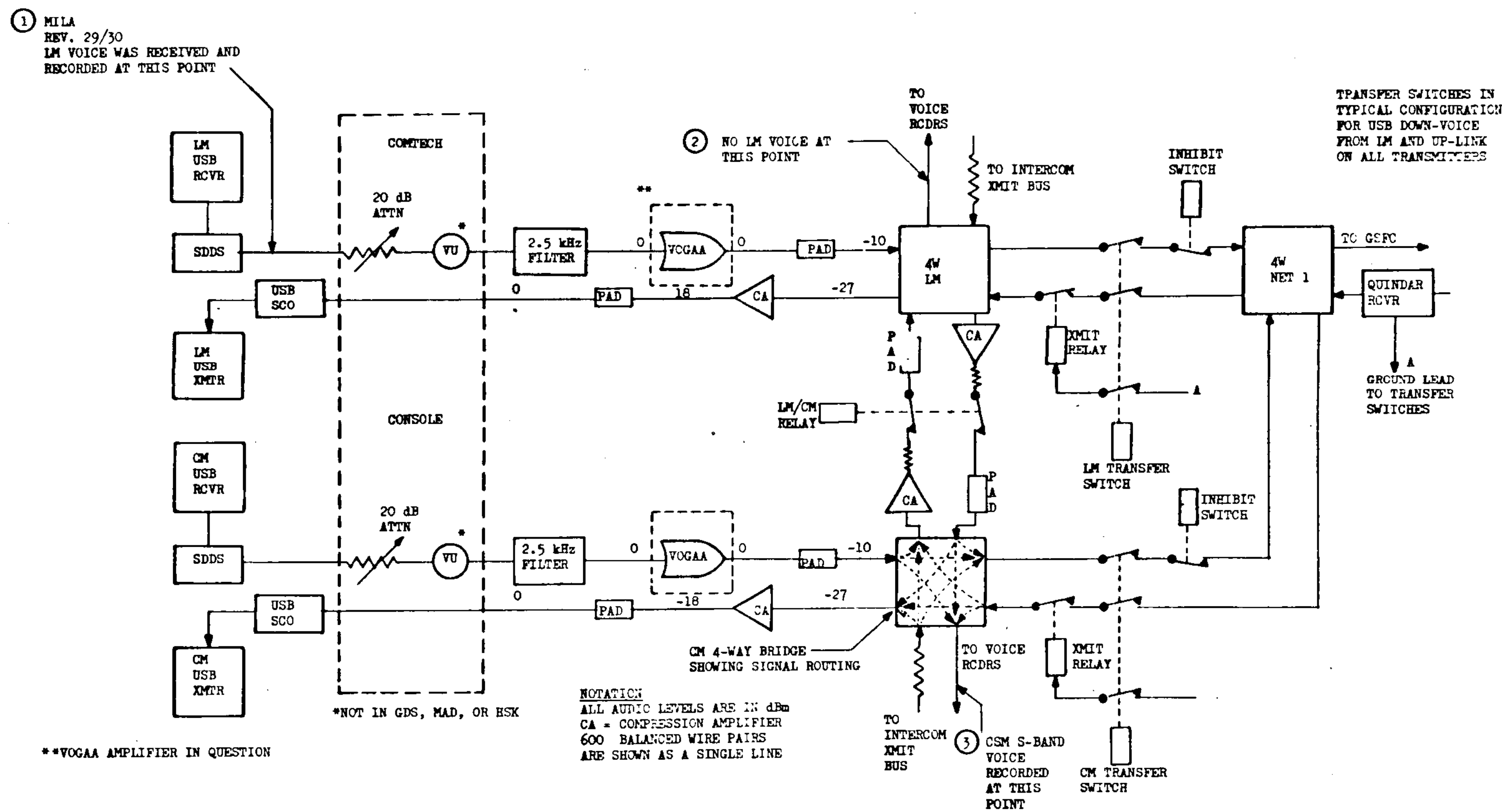


FIGURE 3-5a VOGAA CONFIGURATION

With the mode switch in expansion (E), the VOGAA will enhance (amplify) voltage excursions that go above the trigger point (-22 dBm). The introduction of noise causes the trigger point to increase. With the mode switch in expansion + compression (E + C), the VOGAA will amplify voltage excursions that go above -52 dBm. With the mode switch in compression (C), the VOGAA operates as a conventional feedback amplifier. When the VOGAA is triggered into enhancement, the output will increase from the steady state level to the maximum output limit. The output increase occurs when the mode switch is in position (E) or (E + C).

Upon application of a voltage excursion to the input, the VOGAA will attenuate the first 20 milliseconds. If the speech rate contains excursions at a rate greater than 3 pulses per second the response will become instantaneous.

Input/Output Relations

The following tests were conducted to determine the input/output amplitude relations while operating in the three modes and at different expansion potentiometer settings. In all cases the gain potentiometer was set at midrange. The basic test setup is shown in Figure 3-5 B.

Expansion Mode

The initial VOGAA control settings were gain potentiometer, mid- range; expansion potentiometer, fully counterclockwise; and mode switch, E. Using an 800-Hz sinewave input, the output signal level was plotted for various levels of input signal. The same test was repeated with the expansion potentiometer set up one-quarter from counterclockwise, midrange, and fully clockwise. The data are plotted in Figure 3-6. While operating in the expansion mode, the VOGAA has a linear input/output relation from -60 dBm to -10 dBm. From -10 dBm to +10 dBm, negative feedback is introduced. At no time was the output waveform distorted.

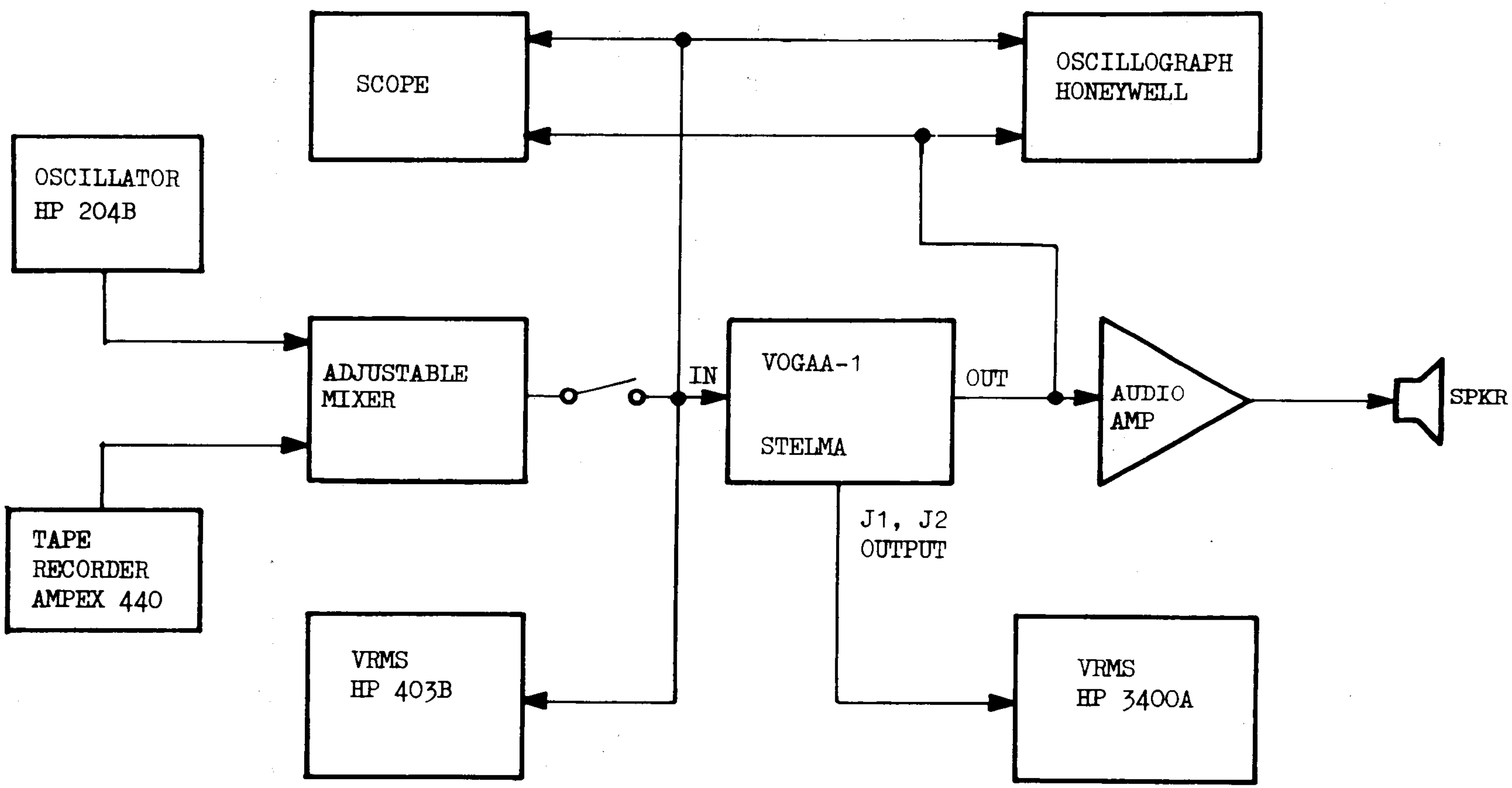


FIGURE 3-5B STELMA VOGAA-1 TEST SET-UP

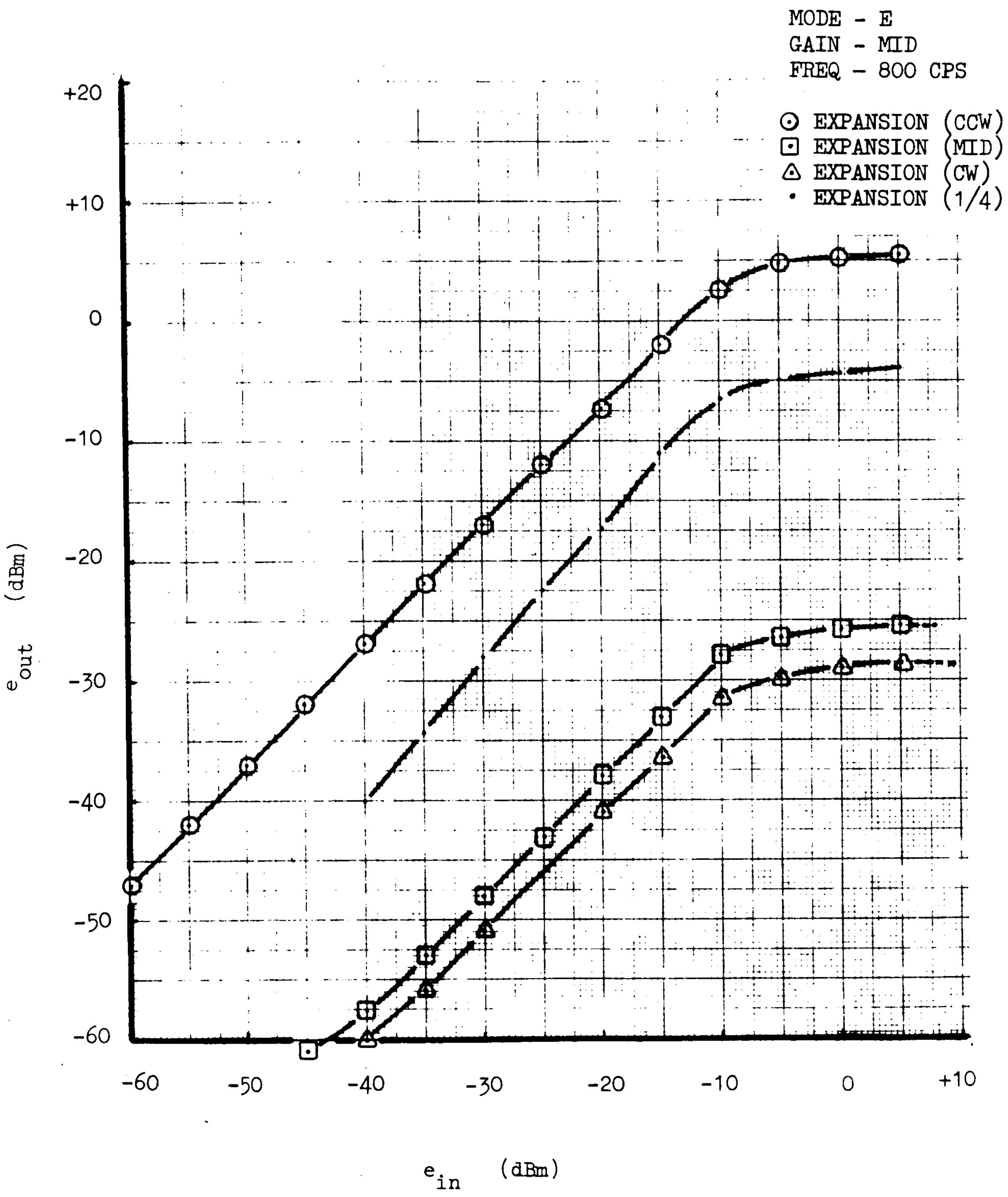


FIGURE 3-6 VOGAA LAB TEST INPUT/OUTPUT RELATIONS, EXPANSION MODE

Expansion Plus Compression Mode

The same input/output amplitude tests were performed with the mode switch at E + C (see Figure 3-7). In this mode, the VOGAA is operating as a feedback amplifier. From -60 dBm to -40 dBm, the input/output relation is linear, and from -40 dBm to +10 dBm, negative feedback is introduced to limit the output level. At no time was the output distorted.

Compression Mode

The same input/output amplitude tests were performed with the mode switch in C. (See Figure 3-8). In this mode, the expansion potentiometer has no effect on the output level. From -60 dB to -40 dB input, the input/output relation is linear, and from -40 dB to +10 dB input, the amplifier output is limited by negative feedback.

Frequency Response

The equipment was connected as shown in Figure 3-5B. The mode switch was at E and the gain potentiometer at midrange. The input level was set at -30 dB. See Figure 3-9 for the passband. The 3 dB points are at 500 Hz and 9 kHz.

Enhancement Threshold

The following tests were conducted to determine the input levels that would trigger the VOGAA into enhancement operation. Various levels of random noise from no noise to zero dB were mixed with an 800 Hz tone.

Attack Time

This test was conducted to determine the time required for the VOGAA to react to an increase in signal level and the time required for the VOGAA to suppress a constant signal level.

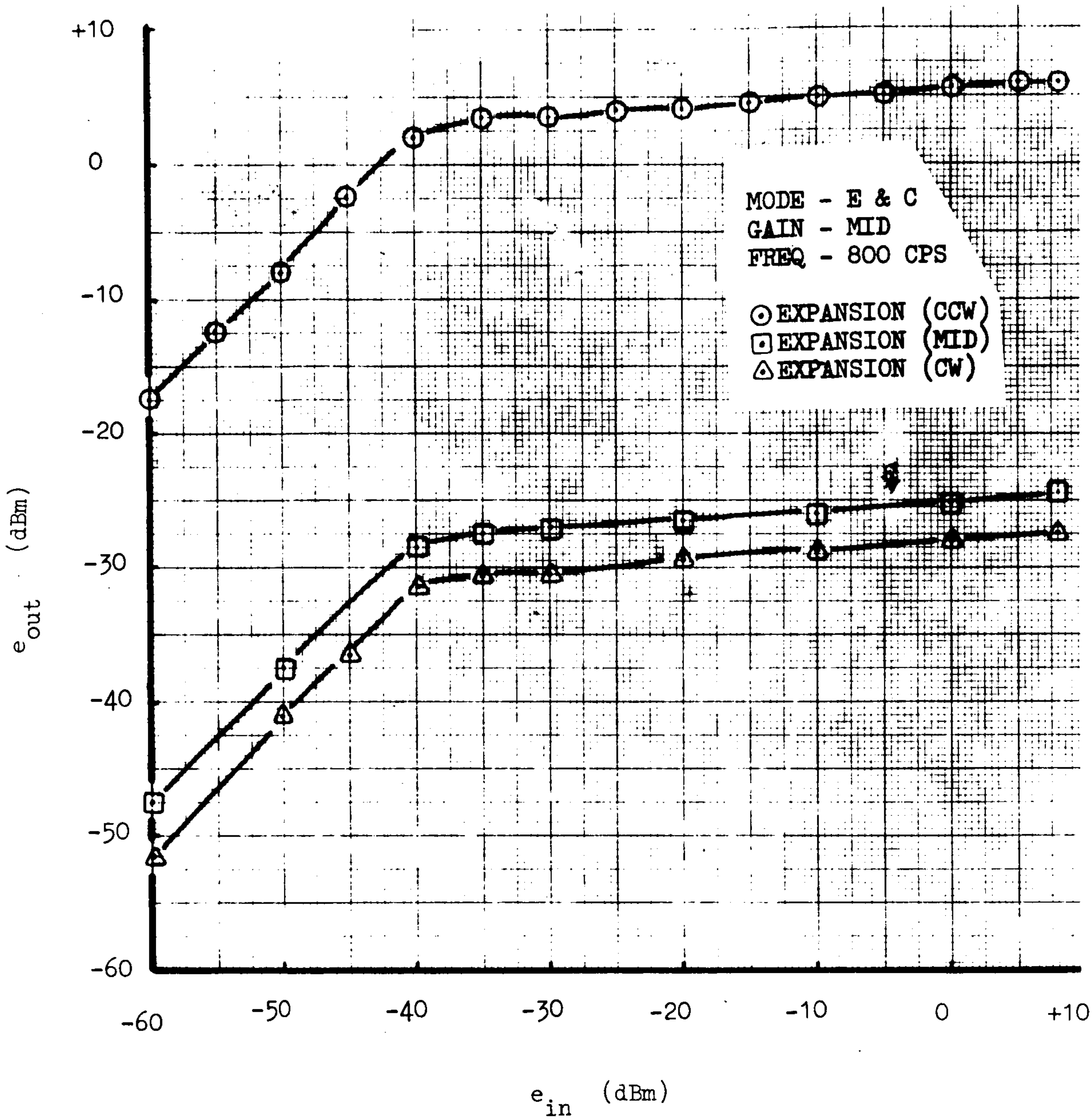


FIGURE 3-7 VOGAA LAB TEST
INPUT/OUTPUT RELATIONS,
EXPANSION & COMPRESSION MODE

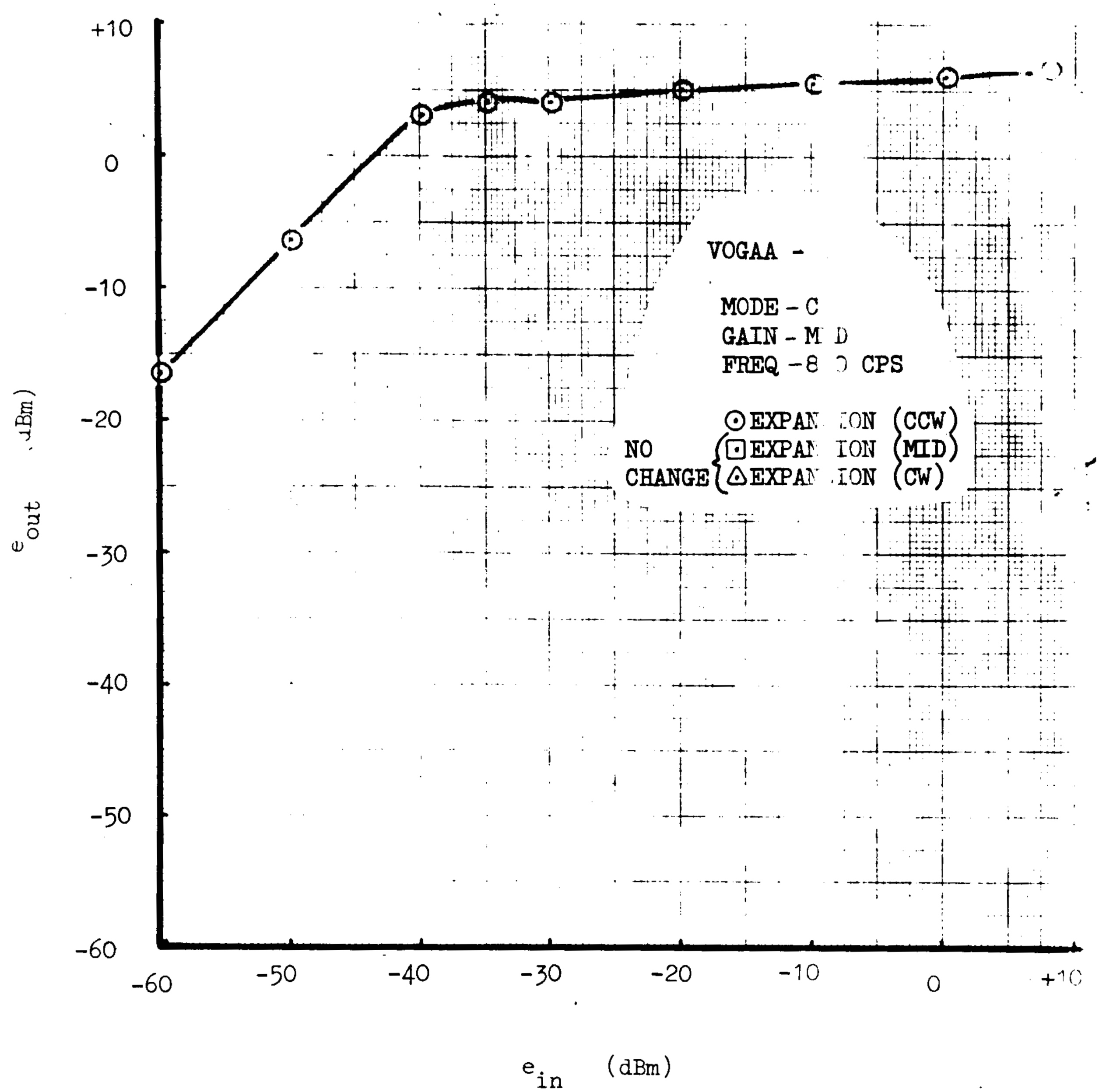


FIGURE 3-8 VOGAA LAB TEST
INPUT/OUTPUT RELATIONS,
COMPRESSION MODE

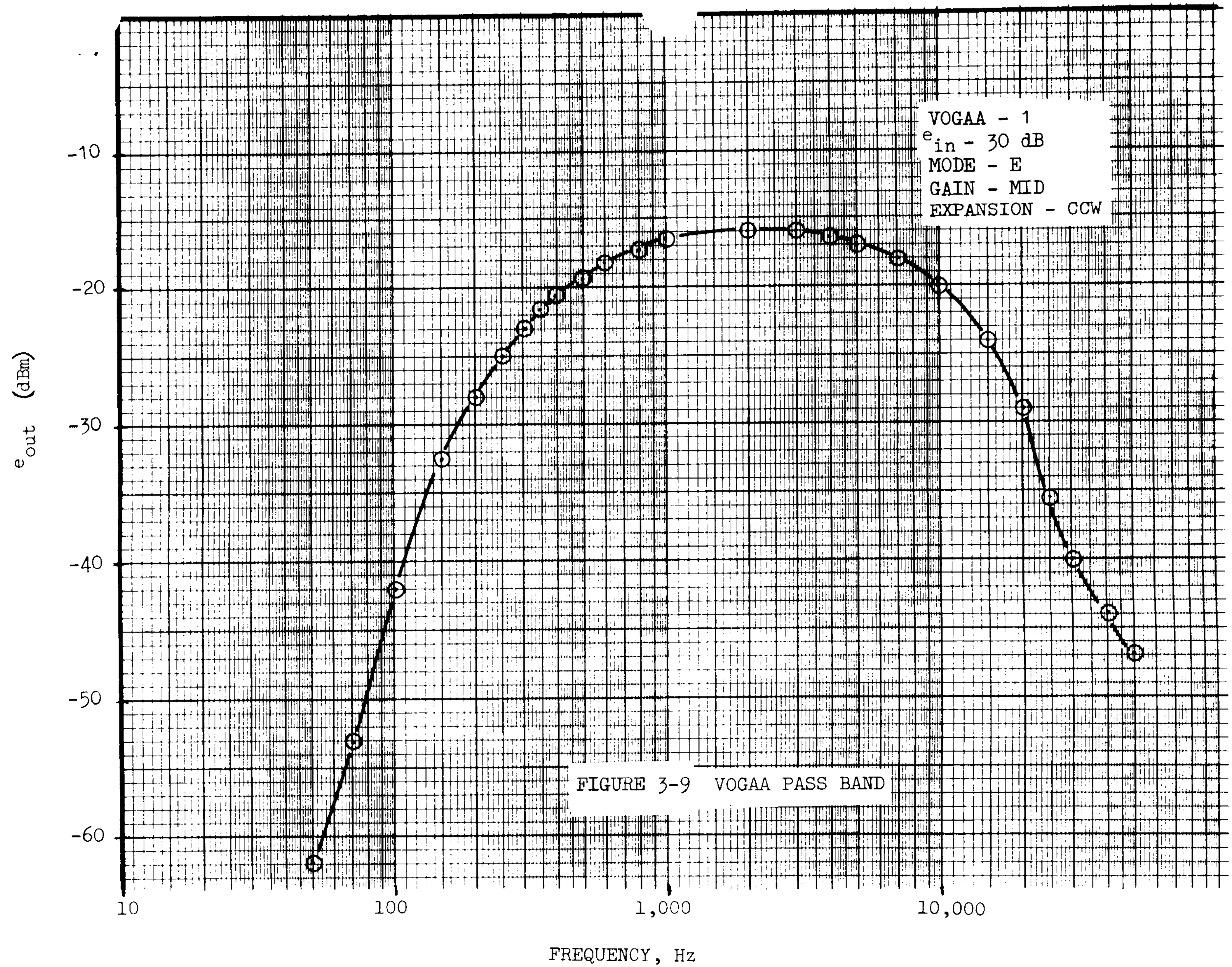


FIGURE 3-9 VOGAA PASS BAND

The VOGAA was operating in the expansion mode, with the expansion and gain potentiometer at midrange. A 0-dB, 800-Hz signal was switched on and off at a 1 pulse-per-second rate and the output was recorded on an oscillograph (see Figure 3-10). The time required to react to 0-dB signal is 20 ms, after which the VOGAA output will increase to its maximum output level. It will maintain this level for 460 ms and then begin to suppress the output. The fall time is 52 ms.

A -20-dB, 800-Hz signal was switched on and off at the same 1 pulse-per-second rate. The oscillograph showed that the delay time was still 20 ms after the delay. The output remained at the maximum level for 345 ms, and then suppressed the output in 45 ms (refer to Figure 3-11).

Repetition Rate Versus Delay Time

This test was conducted to determine the effect of repetition rate on the VOGAA delay time. A 0-dB, 800-Hz sine wave was switched on and off at various repetition rates; (the on time was 43 ms). The output was recorded on an oscillograph and the data plotted in Figure 3-12. For repetition rates up to 2 pulses-per-second, the output was delayed 20 ms. From 2 to 3 pulses-per-second, the delayed portion of the output increases in amplitude until there is no delay in response. This amplitude is plotted in Figure 3-12.

Tone Susceptibility

This test was conducted to determine the effects of a stationary tone upon the operation of the VOGAA. The voice source was Apollo flight tape No. 09-00747, command module PLSS voice (Channel 11). The voice was filtered by a 2.5-kHz low pass filter and then mixed with a 2.4-kHz sine wave.

(TIME IN MILLISEC)

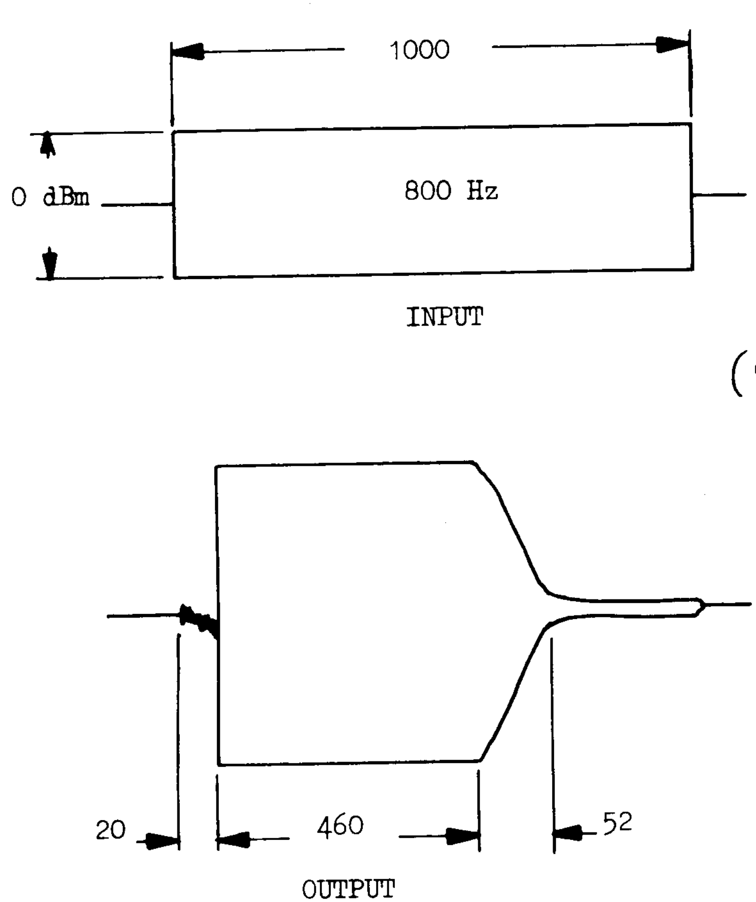


FIGURE 3-10 VOGAA LAB TEST ATTACK TIME, 0 dBm INPUT

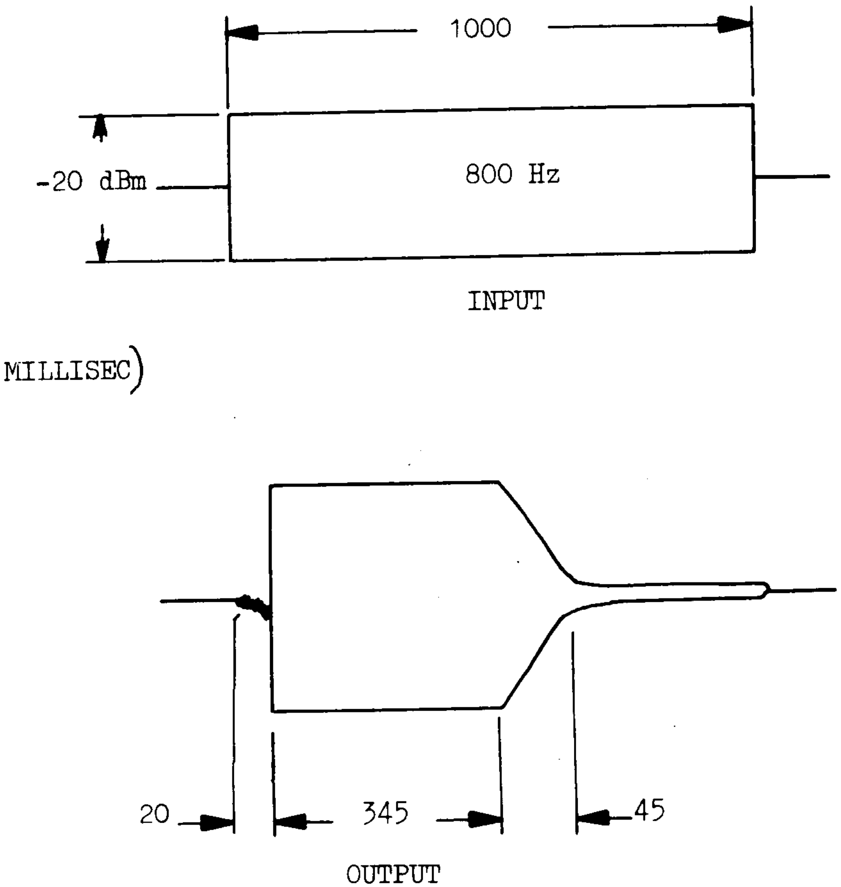


FIGURE 3-11 VOGAA LAB TEST ATTACK TIME, -20 dBm INPUT

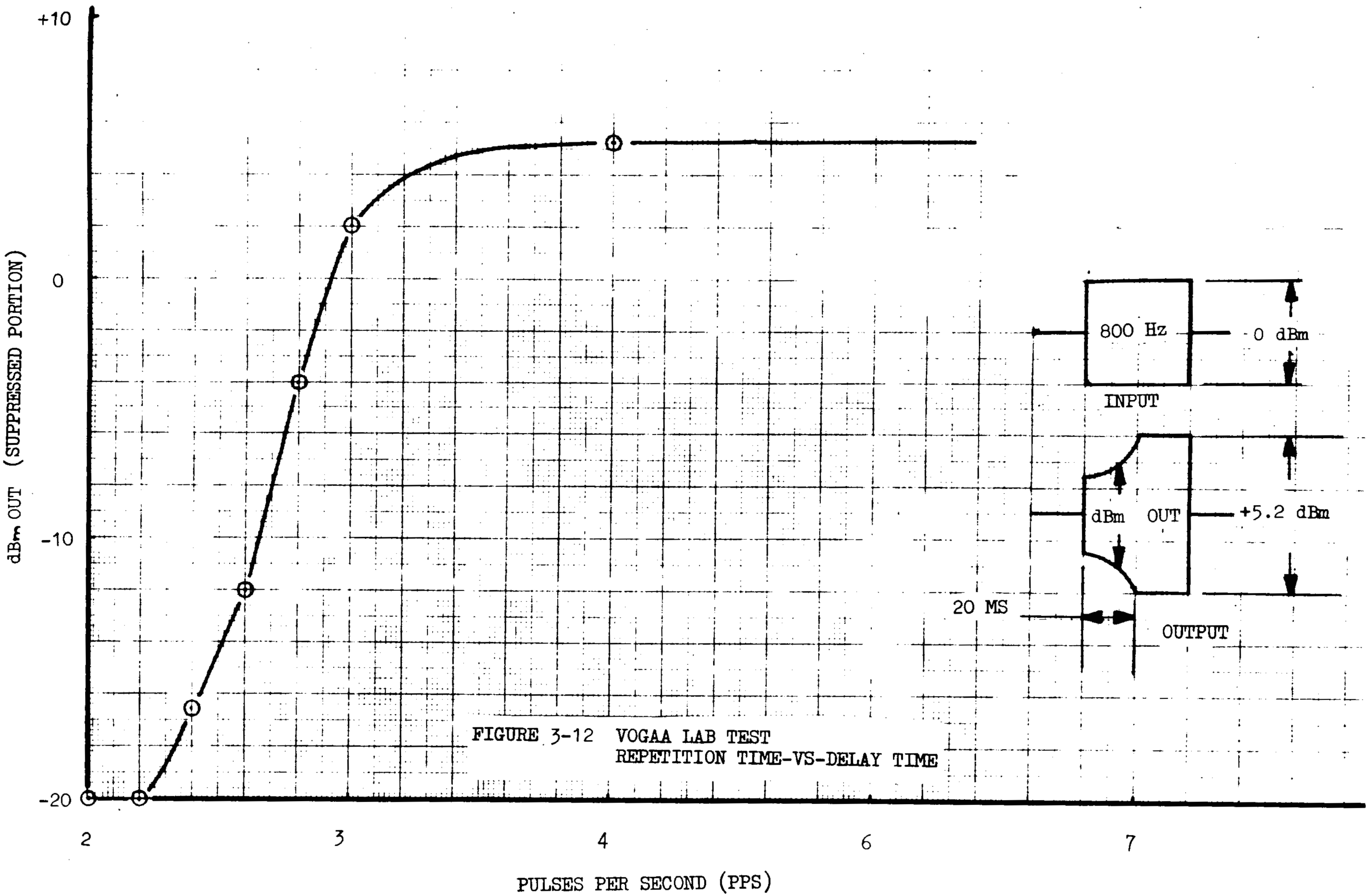


FIGURE 3-12 VOGAA LAB TEST
REPETITION TIME-VS-DELAY TIME

The voice peaks were adjusted to approximately 0-dB and the 2.4-kHz sine wave was varied in amplitude from -20 dB to +20 dB. The VOGAA input and output was recorded on an oscillograph at the various sine wave levels. The total speech time of a particular segment of input voice was equated to 100 percent; the same segment of the VOGAA output voice was time totaled and compared to the input. The input speech-to-noise ratio of each pass (sine wave amplitude at -20, -15, -10, -7, -4, -1, and +2 dB) was also measured. The speech, sine wave amplitude, and percent voice output is compared in Figure 3-13.

The 800-Hz tone was switched on and off at various levels and the level recorded which would trigger the VOGAA.

When the VOGAA is triggered into enhancement, the output will increase from the steady state level (determined by the expansion potentiometer) to the VOGAA maximum output limit. The maximum output is defined by the lack of points plotted for the expansion potentiometer in a fully counterclockwise position. This occurs when the mode switch is in position E or E + C. For example; with the VOGAA in mode E, the expansion and gain potentiometer at midrange, and the noise level at -10 dB, the output will be -28 dB. If a voltage excursion occurs at a 0-dB level, the output will increase to +5 dB and then return to -28 dB.

Expansion Mode

The expansion potentiometer was varied from counterclockwise to clockwise and the 800-Hz switched on and off. Very little difference was noted in the threshold level between the fully counterclockwise and clockwise position of the expansion potentiometer. Therefore, only the midrange data is included. Figure 3-14 is a plot of input noise level versus S+N/N ratio in dB. The shaded area indicates ratios at which the VOGAA will not enhance the input amplitude excursions. Any

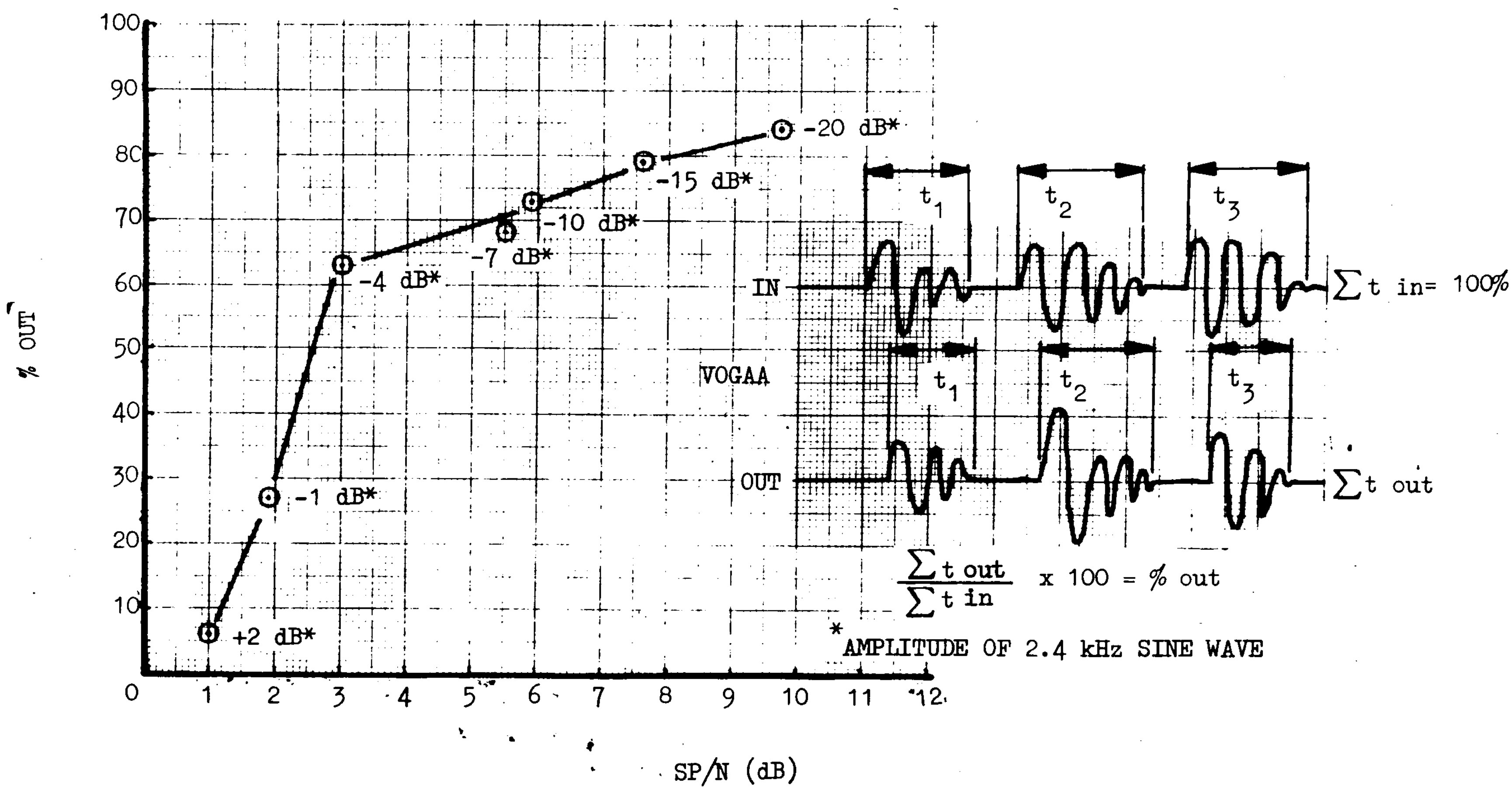


FIGURE 3-13 VOGAA LAB TEST
TONE SUSCEPTIBILITY

ratio above the curve will consistently trigger the VOGAA. With no input noise, the VOGAA trigger level is -22 dB. With a varying noise level, the trigger level will also vary.

Expansion + Compression

The same test was performed with the mode switch in E + C position. The results are plotted in Figure 3-15. With no input noise, the VOGAA trigger level is -52 dB. An increase in the noise level will also increase the trigger threshold.

Conclusions

Figures 3-14 and 3-15 show that for low speech-to-noise ratios (below about 3-dB) at the input to the VOGAA, intermittent voice will occur at the VOGAA output. Figure 3-13 shows that if a tone is present within this speech spectrum, intermittent voice will also occur at the VOGAA output.

It seems very improbable that the VOGAA would have completely inhibited all voice transmissions during the entire Merritt Island revolution 30 pass. Laboratory tests show that even when the VOGAA is not properly setup or when the input speech-to-noise ratios are low some intermittent voice will appear on the output. It seems more likely that a patching problem existed or that the input level to the VOGAA was too low.

Conditions described above and in Figures 3-13, 3-14, and 3-15 are present during Apollo missions; therefore, it would be advisable to insure that, if the VOGAA is used in the Manned Space Flight Network station voice loops, appropriate procedures are implemented to bypass the VOGAA when S-band downlink voice starts to become inhibited. It is also recommended that a voice monitoring meter be placed directly on the input and output of the VOGAA to insure that voice transmissions are not interrupted by the VOGAA amplifier.

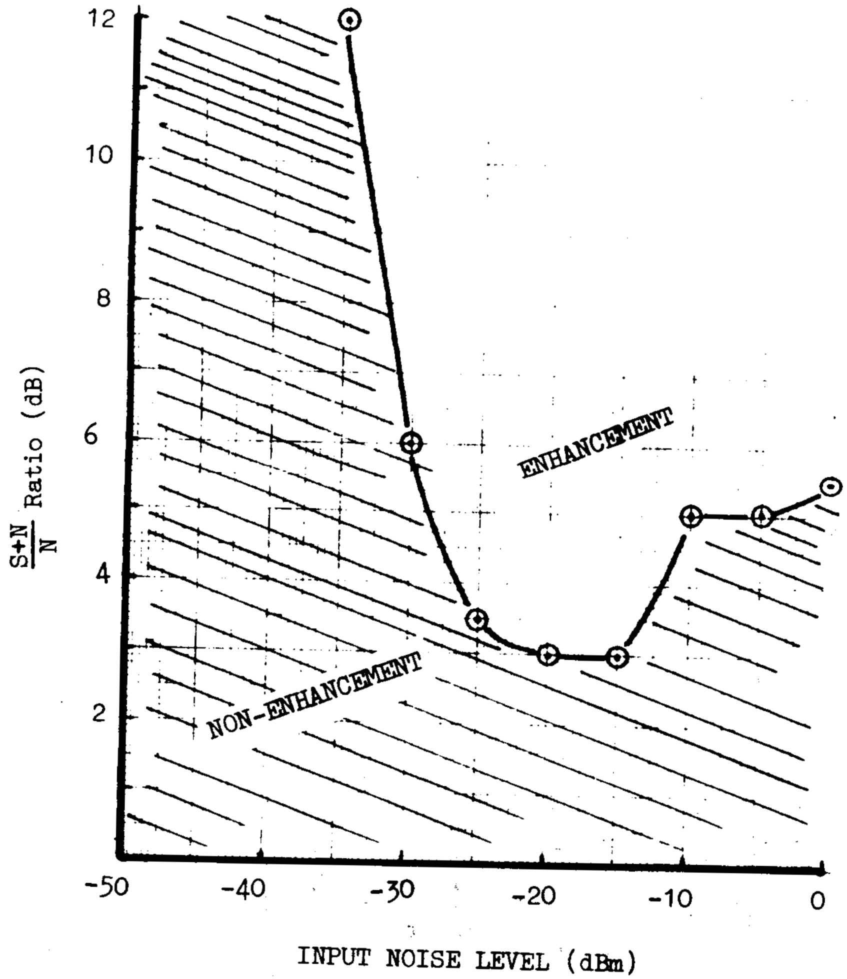


FIGURE 3-14 VOGAA LAB TEST
ENHANCEMENT THRESHOLD,
EXPANSION MODE

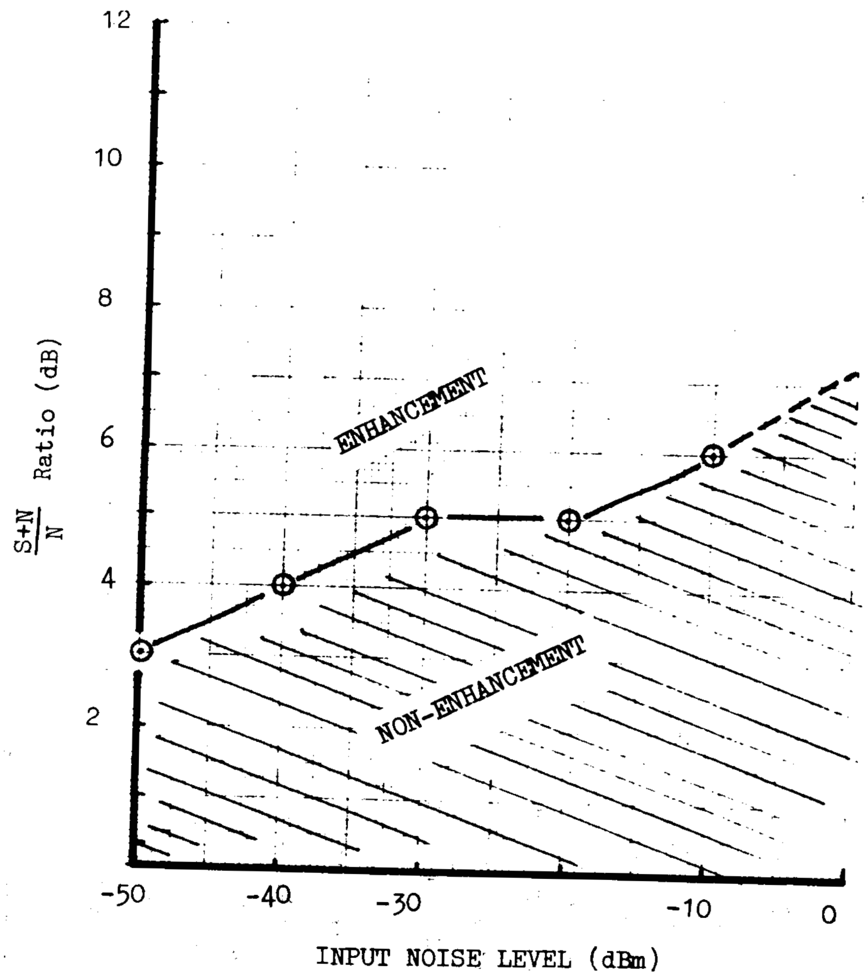


FIGURE 3-15 VOGAA LAB TEST
ENHANCEMENT THRESHOLD,
EXPANSION + COMPRESSION MODE

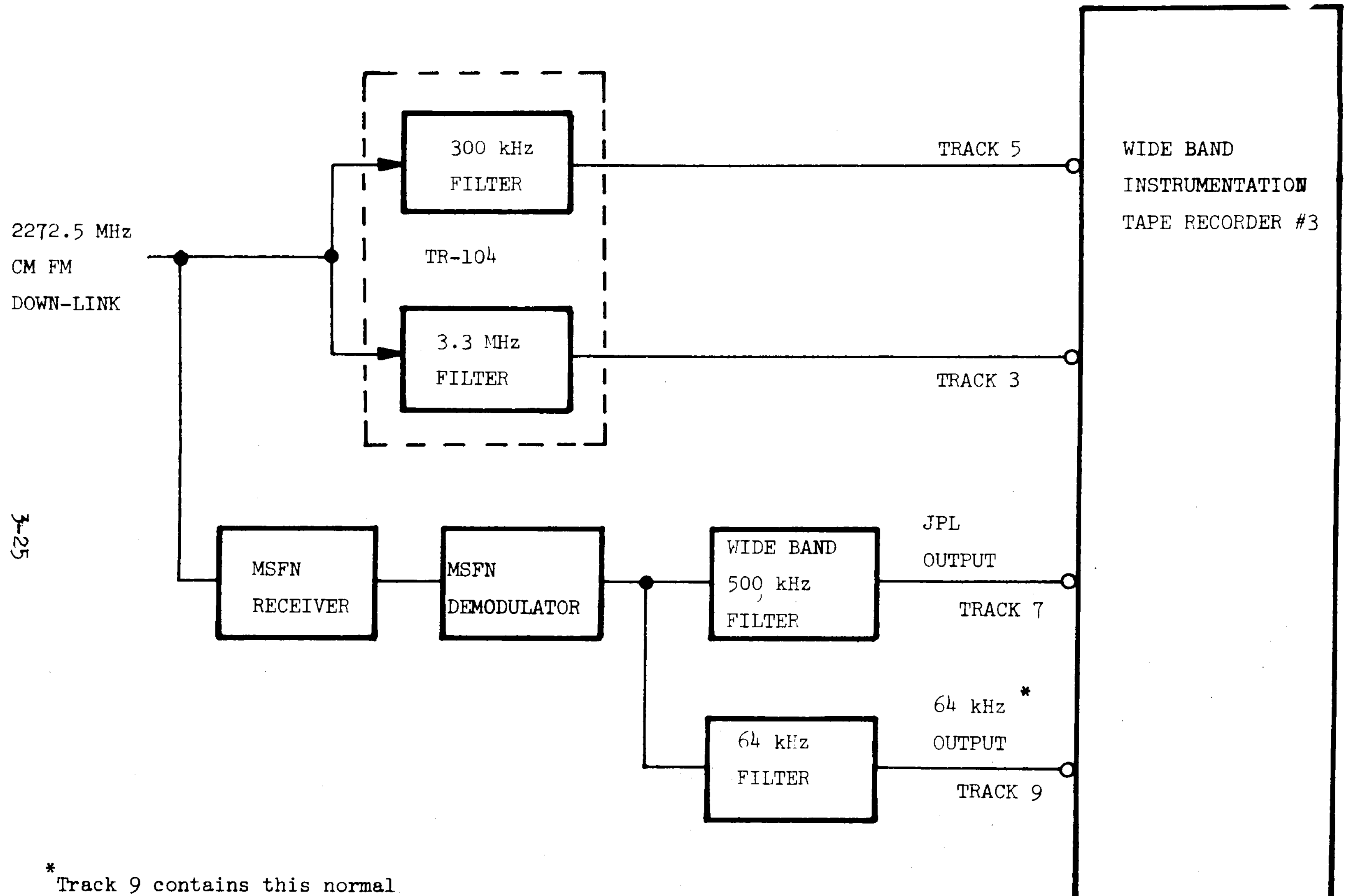
3.4 Data Storage Equipment (DSE) Dump Tone Investigation

During the Apollo 9 mission, undesirable tones were reported in the command module frequency modulation mode 2, 32:1 voice dump playback at several sites. These reports were from sites that use the new ACL TR-104 receivers. The ACL receiver is a dual bandwidth unit of 300-kHz and 3.3-MHz. These tones were diagnosed as products of the command module scientific subcarriers generated by the narrow band filtering of the frequency modulation dump voice spectrum.

None of the sites reported tones on the 1:1 dump during the Apollo 9 mission. However, the revolution 1 Texas 1:1 dump was analyzed, and a 3.15-kHz tone was present. At the present time, the source of the tone has not been identified. The tone did not appreciably affect voice intelligibility. During the Apollo 8 missions, several of the 1:1 dumps contained tones at approximately 380-Hz, 1.1-kHz, and 3.2-kHz. These tones were reported by the sites and were audible when evaluating the station magnetic tapes.

To verify the tones and diagnosis, Texas and Guaymas reconfigured their receivers and tape recorders as shown in Figure 3-16. Dumps were then performed over these two sites to obtain comparison data.

The most extensive evaluation of this problem was accomplished for Guaymas and Texas during revolution 122. The data from these two sites on revolution 122 definitely showed that the undesirable tones occurred when the TR-104 narrow bandwidth was used. However, the frequencies of the tones were not the same at the two sites. Neither were the relative amplitudes of similar frequencies alike at the two sites. Figure 3-17 compares the tones received by the sites during the revolution 122 dump through the narrow bandwidth filter. The tones



*Track 9 contains this normal DSE dump voice output for dual MSFN stations

FIGURE 3-16. **BLOCK DIAGRAM OF SPECIAL DSE DUMP TONE TEST CONFIGURATION (TEX, GYM REV 122)**

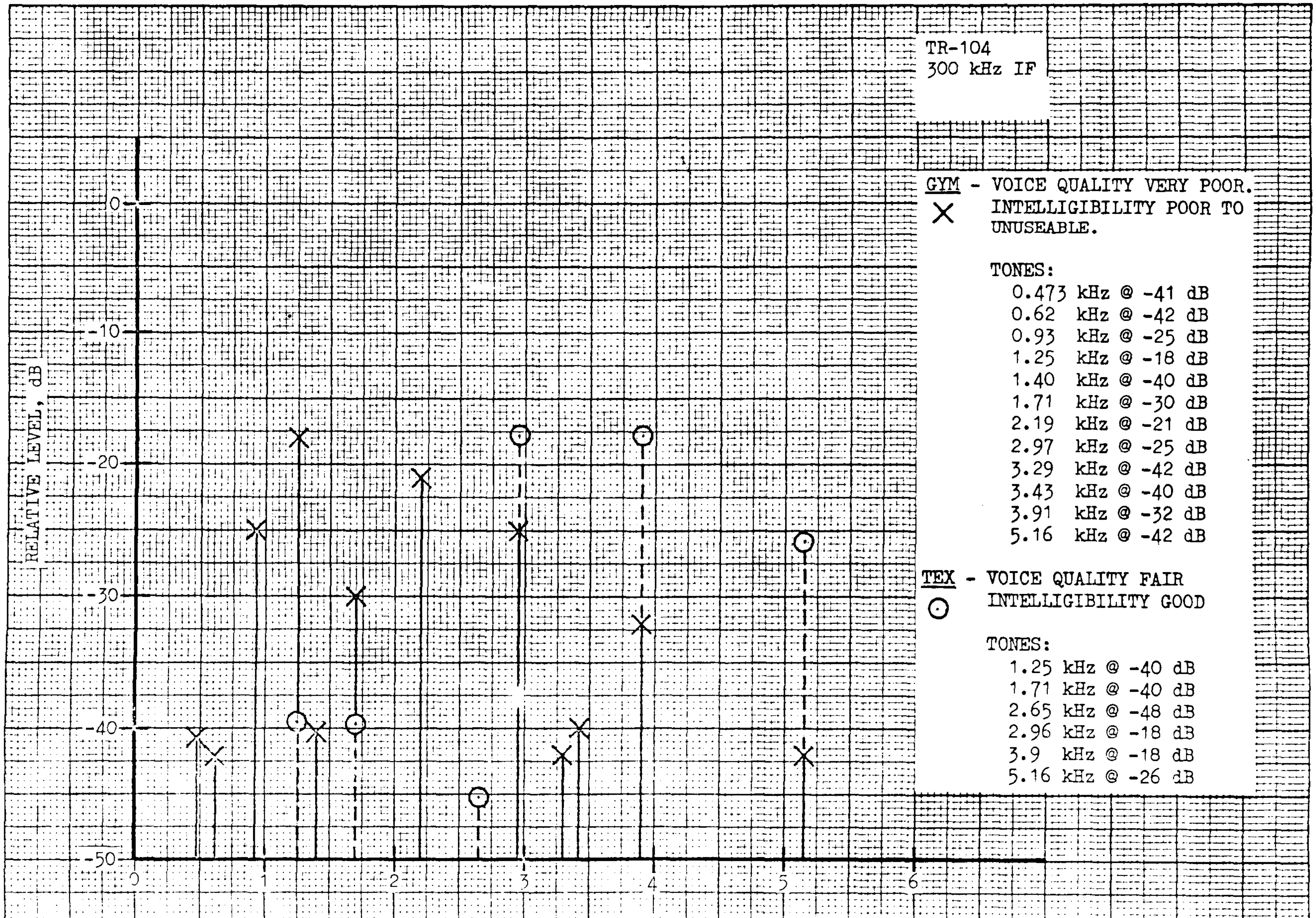


FIGURE 3-17 CSM DSE DUMP TONE SPECTRUM TEXAS AND GUAYMAS, REVOLUTION 122

recorded from the output of the TR-104 3.3-MHz intermediate frequency are presented in Figure 3-18. The three tones that appear are the 95-kHz, 125-kHz, and 165-kHz scientific subcarriers divided by 32. These tones would be expected using the wide bandwidth filter configuration.

Figure 3-19 presents the tones recorded at the output of the Jet Propulsion Laboratory receiver. Again, the tones produced by the scientific subcarriers were detected as expected. No undesirable cross modulation products were recorded.

The output of the Texas and Guaymas 64-kHz filter during the special test conducted during revolution 122 is displayed in Figure 3-20. The test configuration is given in Figure 3-16. With this test configuration and the results shown in Figure 3-19, no tones would be expected at the output of the 64-kHz filter with the exception of the 95-kHz subcarrier somewhat reduced in amplitude. The reason that various frequency components do appear in this output is unknown. It is possible that the 64-kHz filter was not configured as shown in Figure 3-16.

It appears that the presence of the superfluous tones in itself was not the primary cause of poor quality and unintelligible voice. The background noise during the Guaymas reception of the dump was noticeably higher than the noise present at Texas. The voice quality and intelligible were better at Texas. It was suspected that the TR-104 receiver at Guaymas was not tuned properly. The postmission comments from Guaymas stated that during revolution 138, they re-tuned the TR-104 receiver to center frequency and received good dump voice for the first time in the mission. The detuned receiver at Guaymas would explain the higher noise levels and poorer quality voice performance.

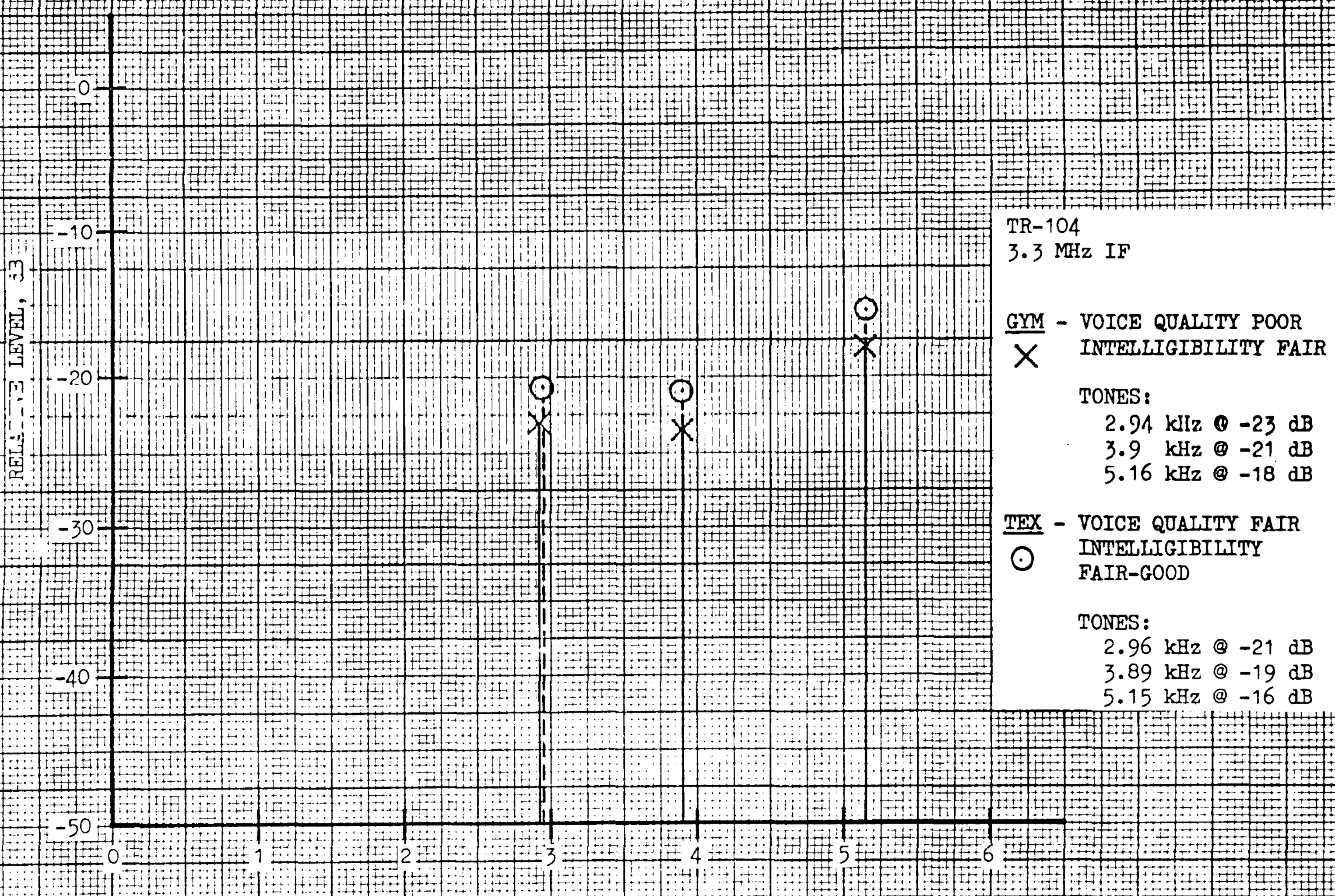


FIGURE 3-18 CSM DSE DUMP TONE SPECTRUM
TEXAS AND GUAYMAS, REVOLUTION 122

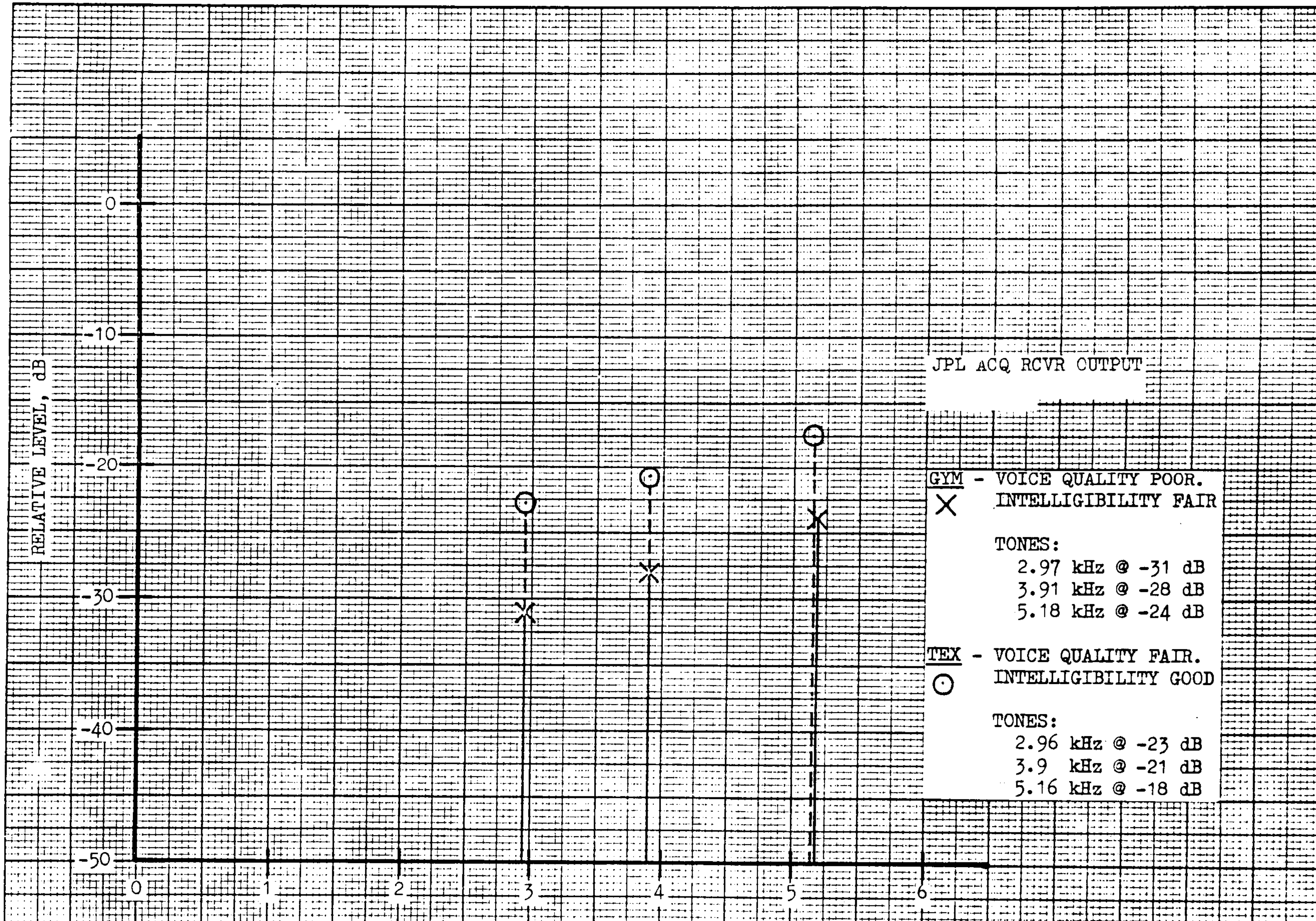


FIGURE 3-19 CSM DSE DUMP TONE SPECTRUM
TEXAS AND GUAYMAS, REVOLUTION 122

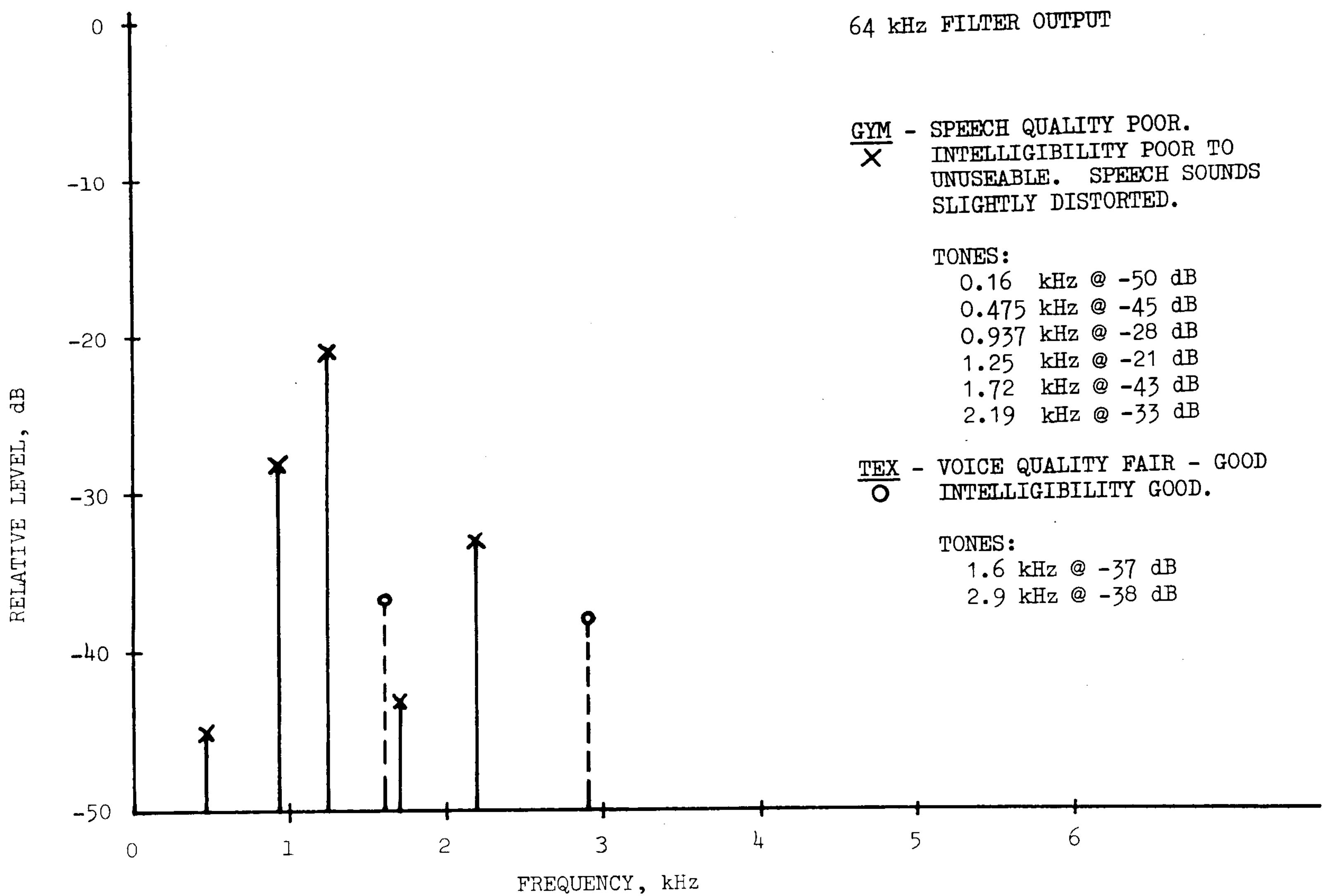


FIGURE 3-20 CSM DSE DUMP TONE SPECTRUM-TEXAS AND GUAYMAS, REVOLUTION 1[illegible]

To further verify that the narrow bandwidth filter does produce the undesirable tones, a special test was conducted in the Electronic Systems Compatibility Laboratory (ESCL). This test was conducted with the command module breadboard and a Nems Clarke R1037F receiver (very similar to an ACL TR-104 receiver). The test consisted of configuring the breadboard for command module frequency modulation mode 2--the scientific subcarriers (95-kHz, 125-kHz, and 165-kHz), the 1.024-MHz pulse code modulation subcarrier, and baseband dump voice (omitted for the test)--and observing the R1037F receiver output for two different intermediate frequency bandwidths. All significant output signals were measured with a Hewlett Packard 310 wave analyzer.

The outputs of the receiver when using the narrow IF bandwidth are plotted in Figure 3-21. The results show that the narrow bandwidth filter causes a nonlinear operation on the scientific subcarriers. This nonlinear operation results in different frequency products from the scientific subcarriers that fall within the dump voice bandwidth. Some of the tones are of sufficient amplitude to interfere with the playback of the dump voice.

There is no common power reference among the curves presented in this section because no calibration data were recorded during any of the special data storage equipment dump tone tests conducted during the Apollo 9 mission. Tone amplitude agreement among the curves in this section should also not be expected because of amplitude differences caused by the narrow band filter not being properly centered about the command module frequency modulation dump voice spectrum. For this reason the tone amplitudes observed at Guaymas 122 and Texas 122 (Figure 3-17) are different from each other and from the tone amplitudes observed during the laboratory test (Figure 3-21). The laboratory test was conducted with the narrow band filter centered about the dump voice spectrum.

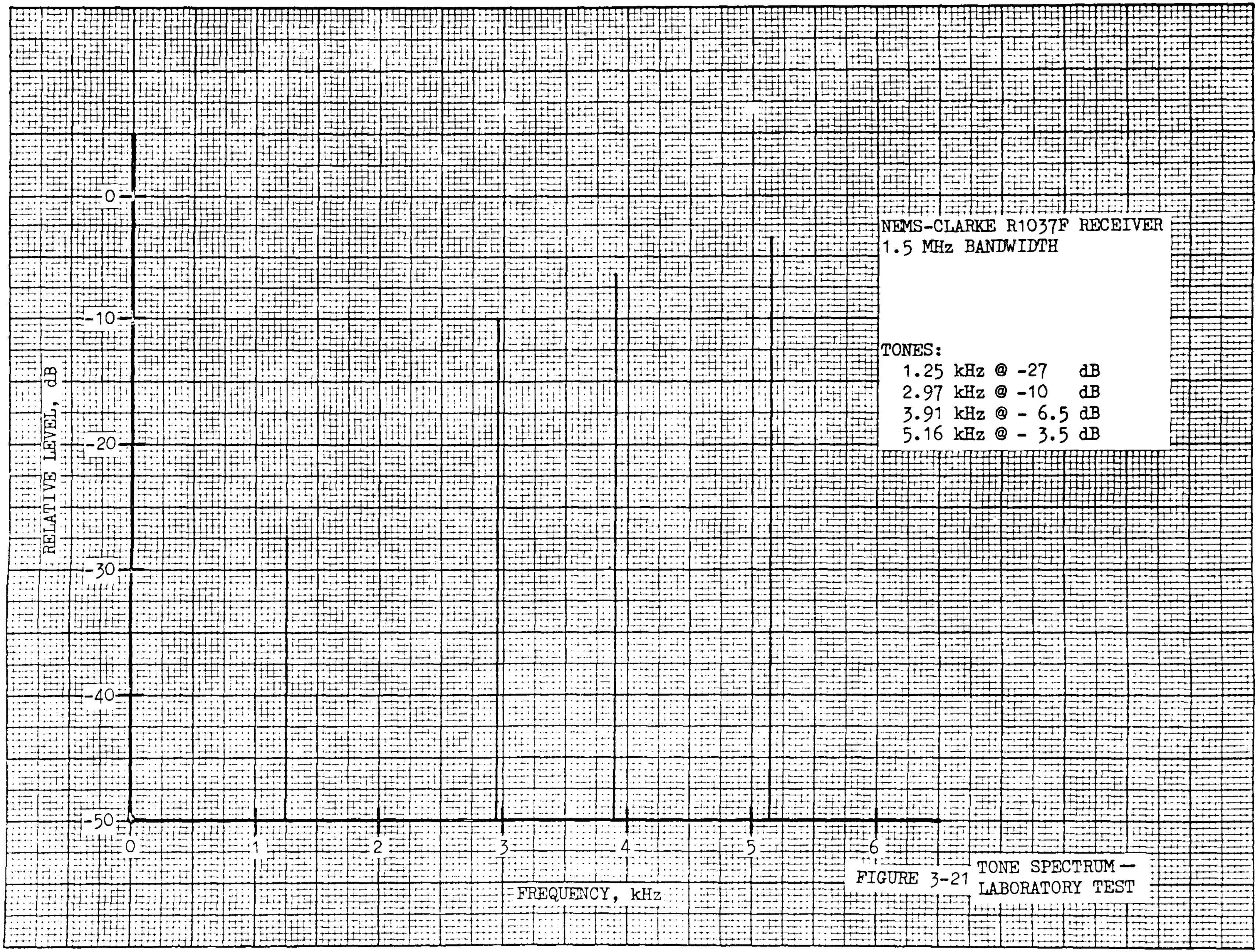


FIGURE 3-21 TONE SPECTRUM — LABORATORY TEST

A comparison of the tones plotted in Figure 3-17 and 3-21 show that large amplitude differences exist for some frequencies. A review of the frequency components plotted in Figures 3-17 and 3-21 shows that for each special test different components appear in the output. This is to be expected since the narrow band filter was centered about different points in the command and service module frequency modulation downlink frequency spectrum.

To provide additional information, a computer program that computes the frequency spectrum of a carrier and its subcarriers was used to generate the frequency spectrum of the 95-kHz, 125-kHz, 165-kHz, and 1.024-MHz subcarriers. Table I lists all the major frequency components of interest from this spectrum program. A comparison of the tones using the narrow-bandwidth filter recorded at Texas on revolution 122, Guaymas on revolution 122, and from laboratory tests are also shown on this table.

The results of the test when using the wide bandwidth IF are presented in Figure 3-22. The cross modulation products were not of significant amplitude when using the 1.5-MHz IF bandwidth. The three scientific subcarriers (divided by 32) appeared in the spectrum as expected. One unexpected frequency component did appear at 1.25-kHz. It is thought that this component was a result of the 1.5-MHz bandwidth not being wide enough to fully accommodate the spectrum. This 1.25-kHz component was not of sufficient amplitude to adversely affect voice quality or intelligibility.

TABLE I

DSE 32:1 DUMP TONE COMPONENTS USING 300 kHz BANDPASS FILTER

Frequency F = Spectrum Components	F/32	TEX-122 TR-104	GYM-122 TR-104	Lab Results	Spectrum Computer Program	
(From Computer Program)					>-40 dB Reference to carrier at 0 dB.	These Tones are audible and may cause interference.
10 kHz	.312 kHz			X		
25	.78			X		
30	.94		X	X		
40	1.25	X	X	X		
55	1.72	X	X	X		
65	2.12					
70	2.19		X	X		
85	2.65	X		X		
95 (Scientific Subcarrier)	2.96	X	X	X		
100	3.12			X		
110	3.44		X			
125 (Scientific Subcarrier)	3.9	X	X	X		
135	4.23			X		
150	4.69					
155	4.75					
165 (Scientific Subcarrier)	5.15	X	X	X		
≡	≡	≡	≡	≡	≡	
5 kHz	.156 kHz			X	<-40 dB	These tones can be neglected.
15	.470		X	X		
20	.62		X			
45	1.40		X			
60	1.87			X		
80	2.51			X		
105	3.29		X	X		

When the TR-104 receiver is in narrow bandwidth (300-kHz) and the receiver is crystal controlled rather than automatic frequency controlled (AFC), it is likely that the receiver filter will not be centered about the downlink spectrum. When the filter is not centered about the spectrum, the cross modulation products produced from the scientific subcarriers will not be canceled out. Incomplete cancellation of these cross modulation products results in a high noise component.

When the spectrum bandwidth exceeds the filter bandwidth, incidental amplitude modulation is introduced into the FM spectrum. During subsequent demodulation of this spectrum, the scientific subcarriers and the various cross modulation components appeared in the output of the receiver.

The use of either the AFC mode (rather than the crystal mode) or the 3.3-MHz IF bandwidth (instead of the 300-kHz bandwidth) would greatly improve performance. Increasing the filter bandwidth to 3.3-MHz eliminates the limiting problem. It also removes the constraint that the TR-104 filter be centered about the downlink spectrum. The 3.3-MHz bandwidth is wide enough to accommodate the worst case combination of the modulation spectrum, doppler, spacecraft transmitter frequency offset, and spacecraft transmitter short-term frequency stability.

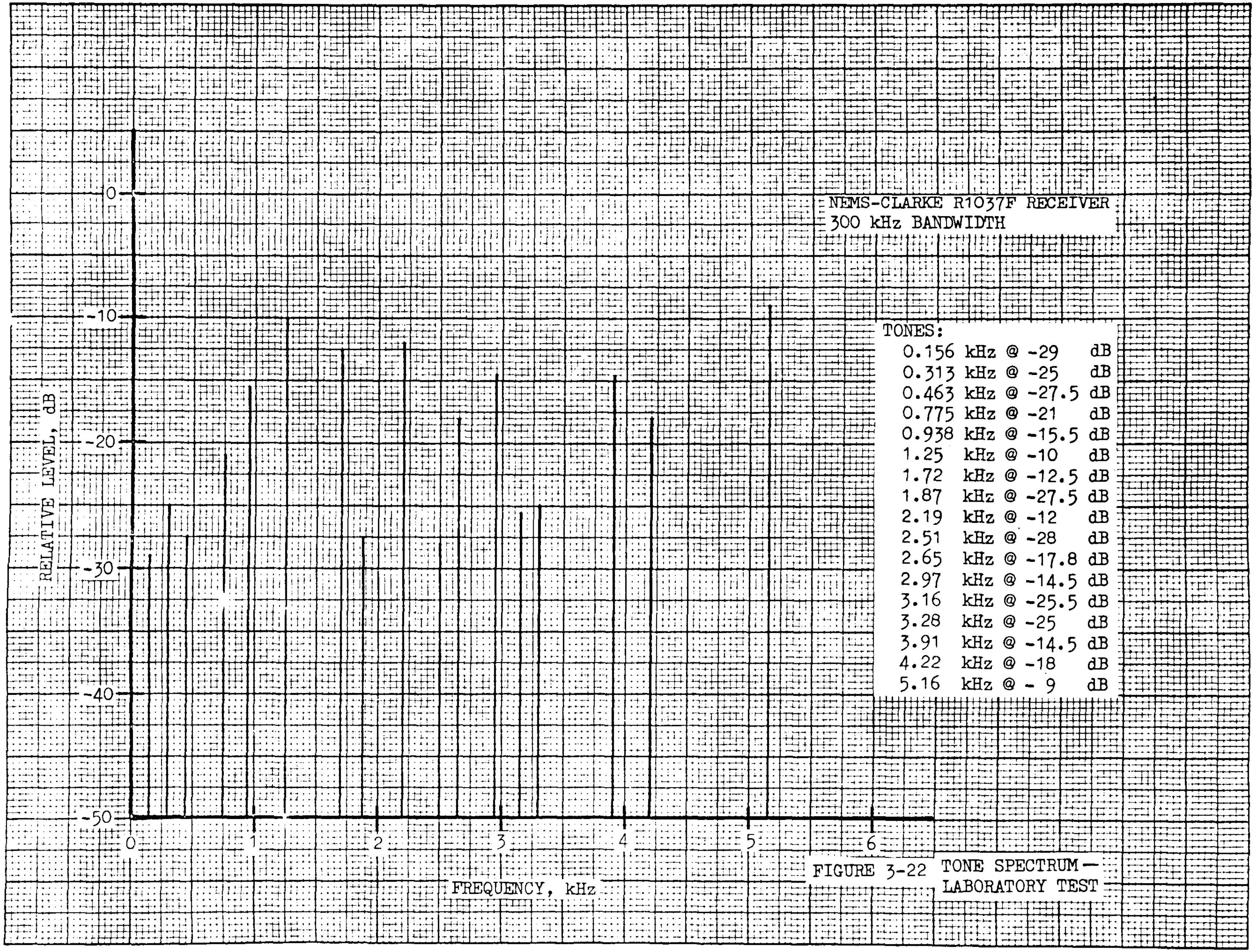


FIGURE 3-22 TONE SPECTRUM — LABORATORY TEST

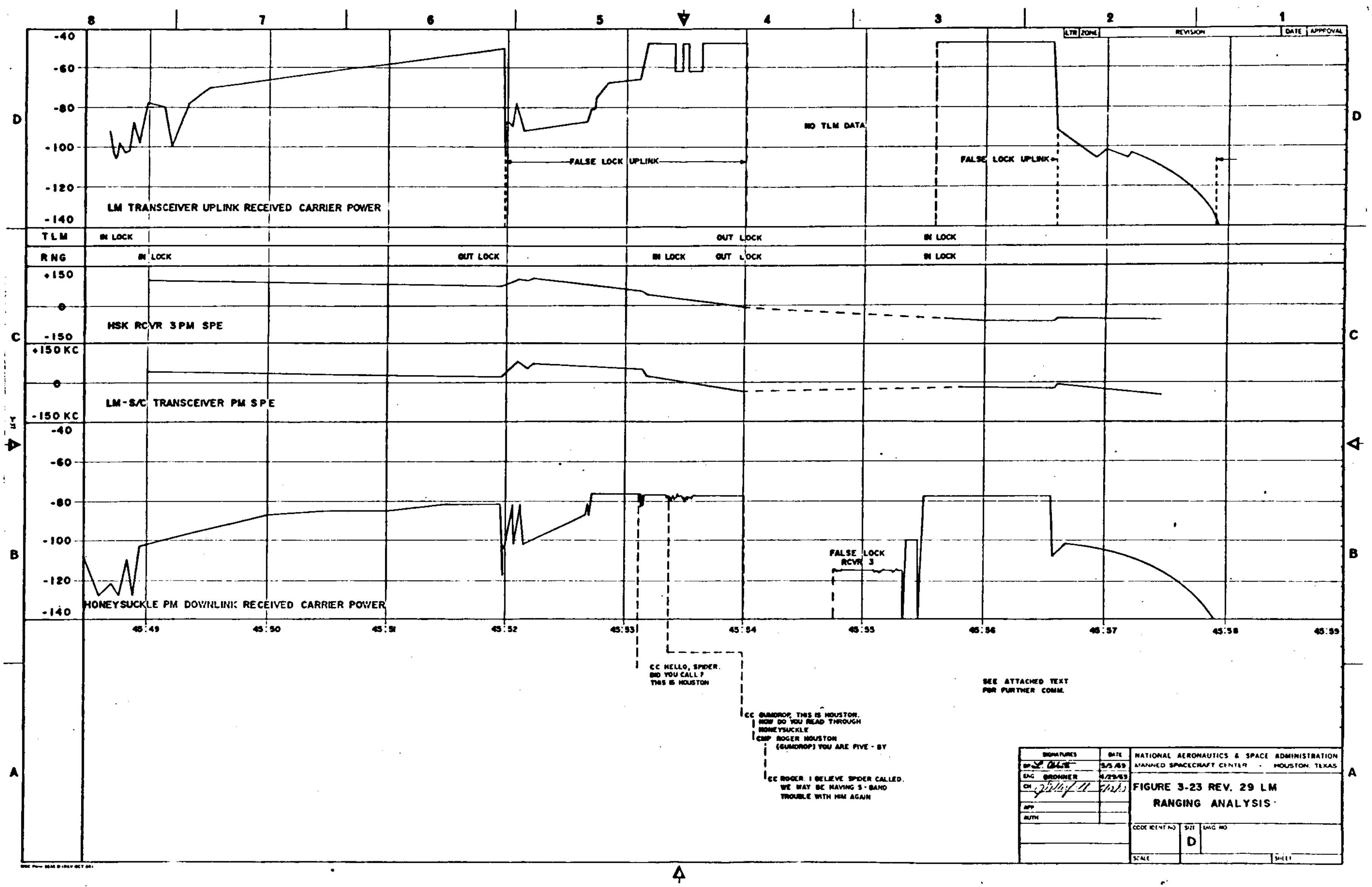


FIGURE 3-23 REV. 29 LM RANGING ANALYSIS

3.5 Lunar Module Ranging And Tracking Discrepancies

During the Apollo 9 mission, several lunar module ranging anomalies occurred. A detailed discussion of these anomalies is presented below.

1. An evaluation of Honeysuckle revolution 29 data indicates an operational problem in maintaining uplink lock during rapid changes of uplink received carrier power. Loss of uplink lock occurred at approximately 045:51:58 when the Honeysuckle antenna slewed off track onto its first side lobe (Figure 3-23).

   The downlink received carrier power dropped abruptly from approximately -88 dBm to a -108 dBm level passing through a null of approximately -35 to -40 dB. (Figure 3-24 and 3-25). Coincidental with this drop in signal, both the lunar module transceiver static phase error and the Honeysuckle receiver static phase error shifted approximately +30 kHz (upvoice subcarrier frequency equivalent.) At 045:52:42 the Honeysuckle antenna re-acquired on the main lobe (on boresight). The uplink and downlink carrier power levels increased proportionately +20 dB. The lunar module transceiver and Honeysuckle receiver static phase error did not change at this time. However, at 045:53:09 the static phase error for both the lunar module transceiver and Honeysuckle receiver shifted approximately +30 kHz. During an upvoice transmission, the uplink received carrier power decreased by approximately 10 dBm while the downlink remained constant at -74 dBm.

   During the period of apparent false lock, the Honeysuckle ranging receiver lost lock because of an apparent loss of turnaround ranging. After the transceiver relocked to the carrier, the ranging receiver locked up, and a range reacquisition was accomplished. There is no indication that the site swept the uplink to achieve proper lock. The main receiver did not drop lock during the

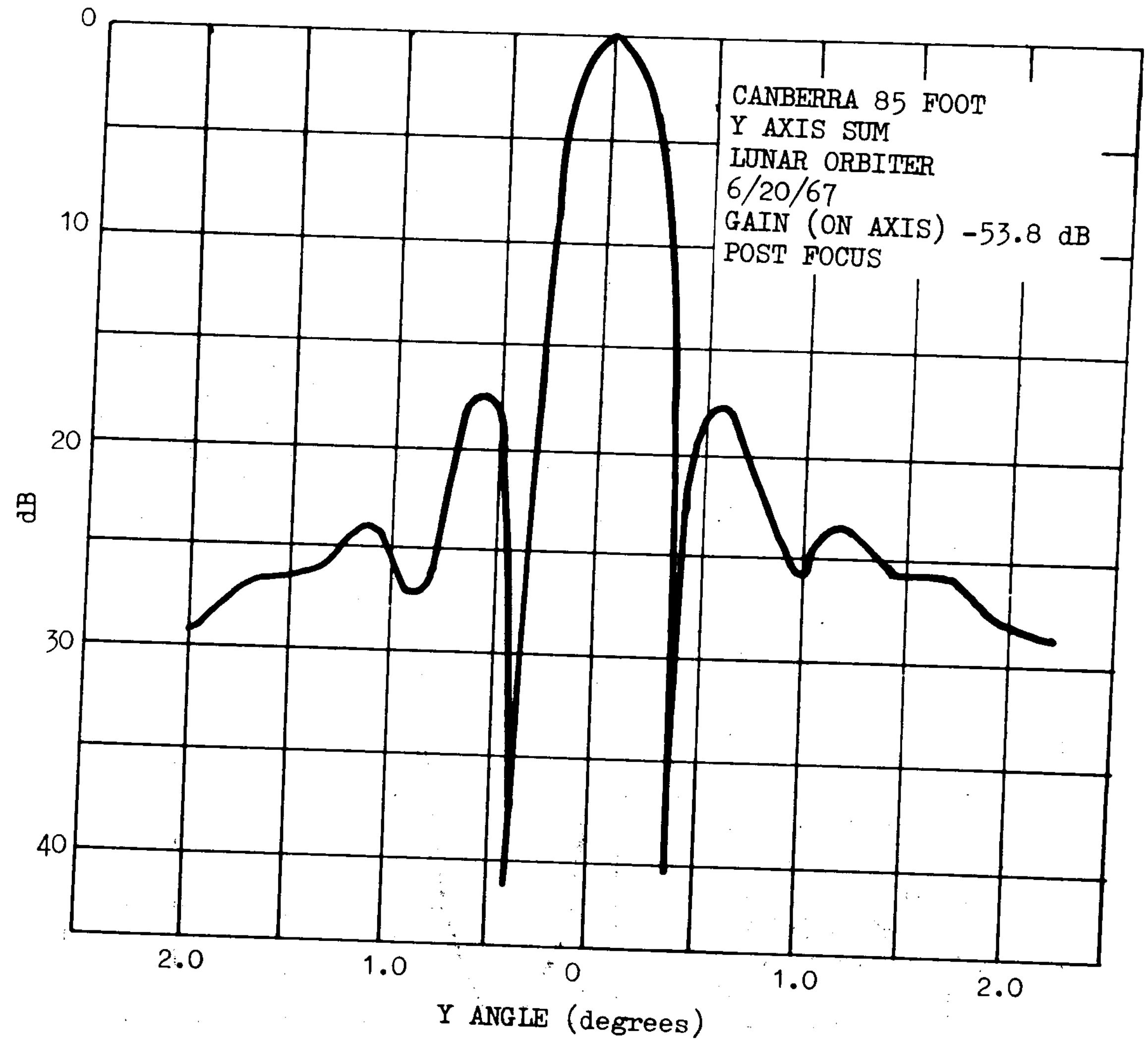


FIGURE 3-24 HONEYSUCKLE 85-FOOT ANTENNA PATTERN (FOR REFERENCE ONLY)

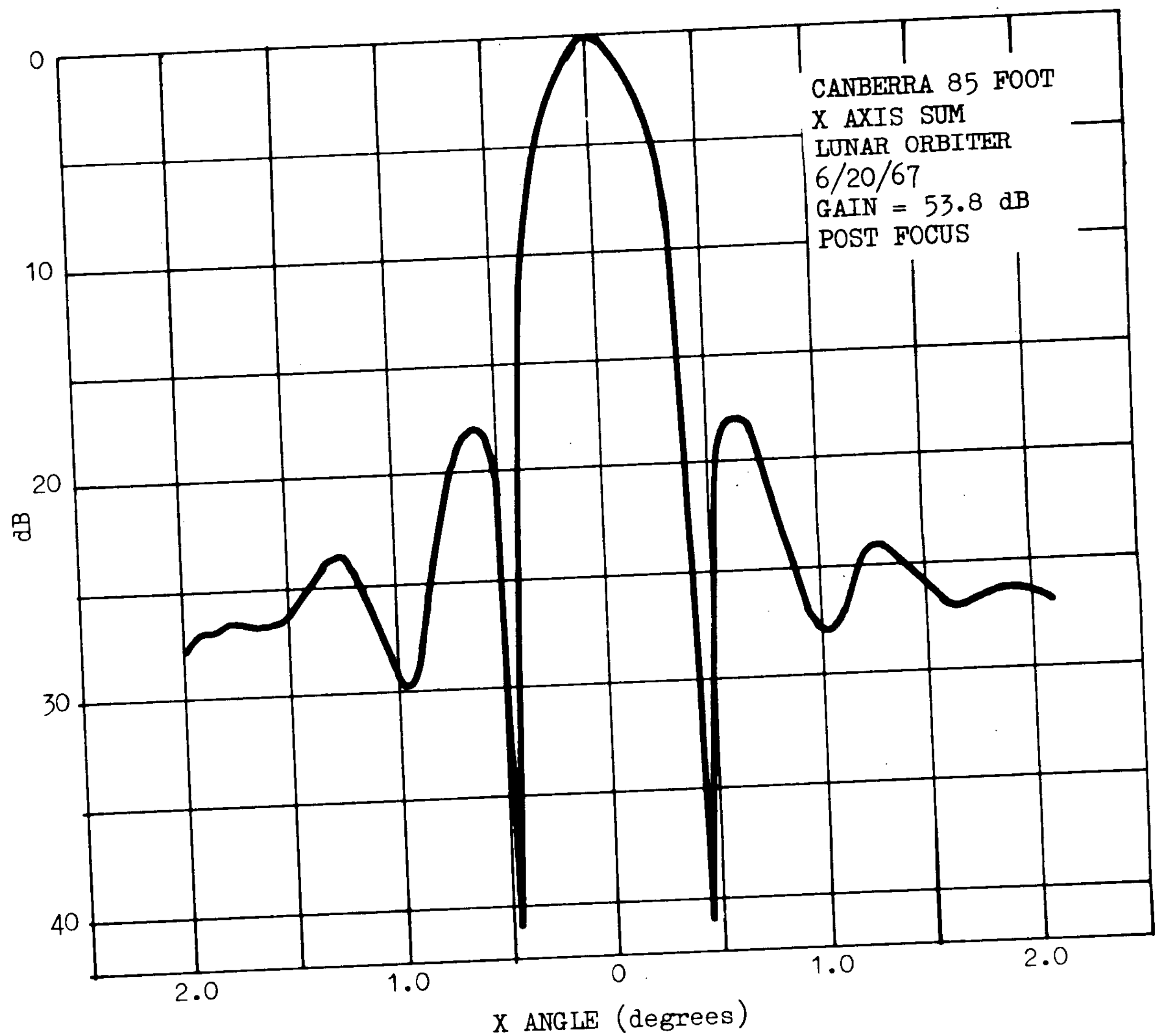


FIGURE 3-25 HONEYSUCKLE 85-FOOT ANTENNA PATTERN (FOR REFERENCE ONLY)

previously referenced events. The command and service module was being tracked on system 1 at Honeysuckle during this pass. The same changes in signal levels were observed, but there was no indication of abnormal or false lock conditions such as that occurring with the lunar module.

S-band lock was again achieved concident with a Manned Space Flight Network S-band voice transmission. It is possible that modulation on the voice subcarrier at this time reduced the power in the 30-kHz side band to which the lunar module was locked to a level low enough that loss of false lock occurred. The transceiver apparently then relocked itself to the uplink carrier.

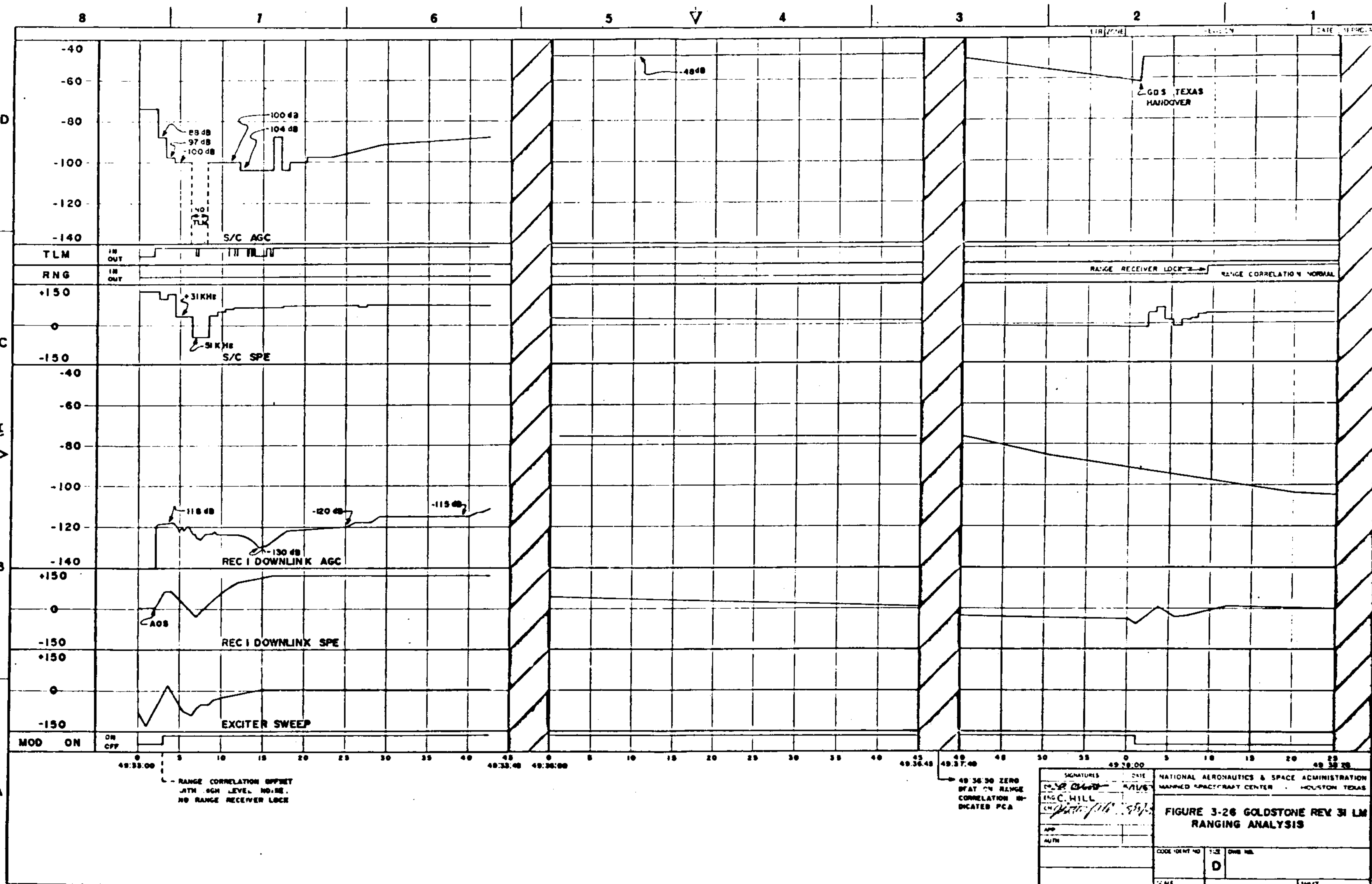
Tests conducted in the Electronic Systems Compatibility Laboratory with a lunar module transceiver of the same type as that flown on lunar module 4, indicate that it will drop carrier lock and lock to the 30-kHz subcarrier when transient drops in total power of approximately 35 dBm occur. This is equivalent to or less than the depth of the null of an 85-foot antenna between the main beam and the first side lobe which is 20-dB below the main beam antenna gain.

2. The Goldstone tracking site was unable to range with the lunar module during revolutions 31 and 32. Ranging performance was normal on revolution 46 and for the remainder of the mission when uplink power was reduced from 2 kilowatts to 450 watts. This was done when it was suggested that 2 kilowatts from an 85-foot antenna site may saturate the lunar module transceiver causing suppression of the ranging signal. This theory has not been validated with a lunar module test transceiver since uplink signal was about -90 dBm at acquisition of signal. Tests conducted in the Electronic Systems Compatibility Laboratory with a high uplink power (-40 dBm) did not suppress ranging.

Prior to the Apollo 9 mission, an engineering change (EI) was installed in the ranging subsystem of the Manned Space Flight Network sites having 85-foot antennas. Previous range acquisition procedures have been modified since installation of EI 3363. This EI allows the ranging technician to adjust for proper correlation indication after acquisition by adjusting the manual gain control at the MK I ranging system. It appears that this modification may cause operational problems. For example, if the manual gain control is adjusted improperly, the range correlation voltage will be incorrect. At a low downlink received carrier power level, it can prevent range code acquisition. However, this was not confirmed during the Electronic Systems Compatibility Laboratory tests.

Evaluation of Goldstone revolution 31 data shows that no range receiver lock was obtained until handover to Texas on revolution 31 (Figure 3-26). An evaluation of Goldstone data indicates that the ranging correlation voltage was modulated by a varying frequency sine wave. At about point of closest approach, a zero-beat frequency was exhibited.

An excessive turnaround doppler for this trajectory of about 120-kHz (normally not above 90-kHz) was observed in the Manned Space Flight Network data. The S-band radio frequency received power differential between the lunar module and the Manned Space Flight Network was about 23-dB. This should have been about 27-dB. The uplink radio frequency signal strength was about -92 dBm, and the down-link radio frequency signal strength was approximately -115 dBm. This indicates that the lunar module could have been locked to the 30-kHz or 70-kHz S-band uplink subcarrier.



NATIONAL AERONAUTICS & SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER · HOUSTON TEXAS

FIGURE 3-26 GOLDSTONE REV 31 LM RANGING ANALYSIS

SIGNATURES	DATE
ENG C. HILL	

CODE IDENT NO | SIZE D | DWG NO.

Another possible cause for the Goldstone revolutions 31 and 32 ranging problem is false lock. The term false lock has been used to describe acquisition to any frequency other than the S-band carrier including lock to modulation sidebands. Station records for Goldstone revolutions 31 and 32 indicate initial lock to spurious signals other than the carrier or modulation sidebands. This condition can occur under certain conditions and can properly be called false lock. Sideband lock can only occur if the station attempts acquisition with modulation on or if carrier lock is dropped after modulation is applied at the ground station.

The Goldstone revolutions 31 and 32 problems appear to be caused by acquisition procedures that prevented uplink carrier acquisition during the handover. Figure 3-27 shows a block diagram of the station exciter. Transmitter power on is accomplished by switching the 66-MHz drive to the X4 frequency multipler module. During this initial turnon, the exciter output will contain many spurious signals until X4 and X8 multiplers stabilize. If the lunar module transceiver acquires one of these spurious signals and the ground receiver is locked to the downlink, the system will appear to be in two-way lock. When modulation is applied under these conditions, the lunar module transceiver can acquire lock on any frequency component in the modulated uplink spectrum.

The lunar module transceiver is more susceptible than the command module transponder to these false lock modes since the lunar module tracking loop bandwidth is 1100-Hz and the command module is 800-Hz. Therefore, the lunar module will track at a higher rate. The probability of false lock can be reduced during acquisition if modulation is applied after the exciter sweep is decayed. In addition, station operators should be alert to the possibility of false lock, and if the system appears to be in a false lock mode, they should initiate a reacquisition procedure.

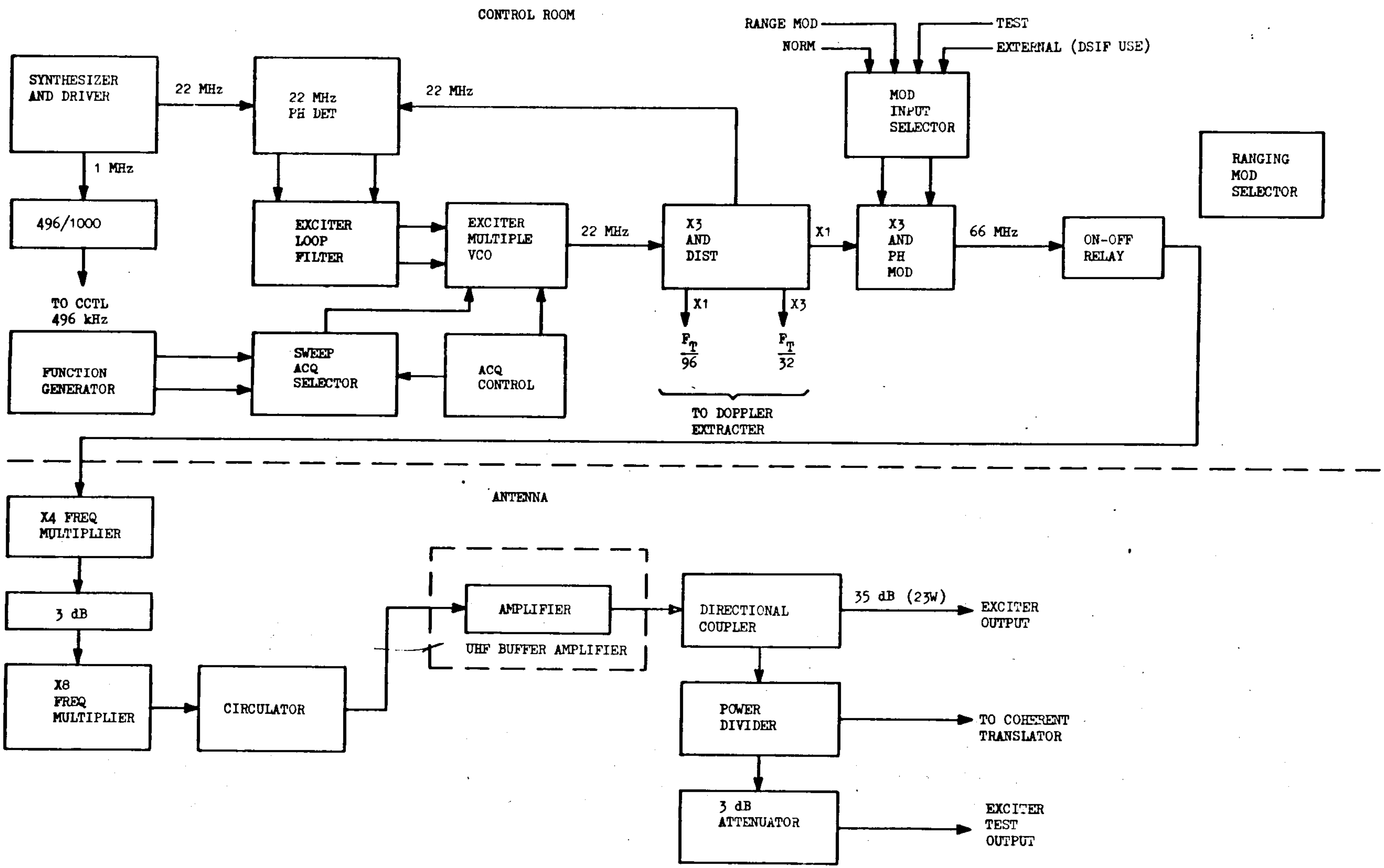


FIGURE 3-27 EXCITER BLOCK DIAGRAM

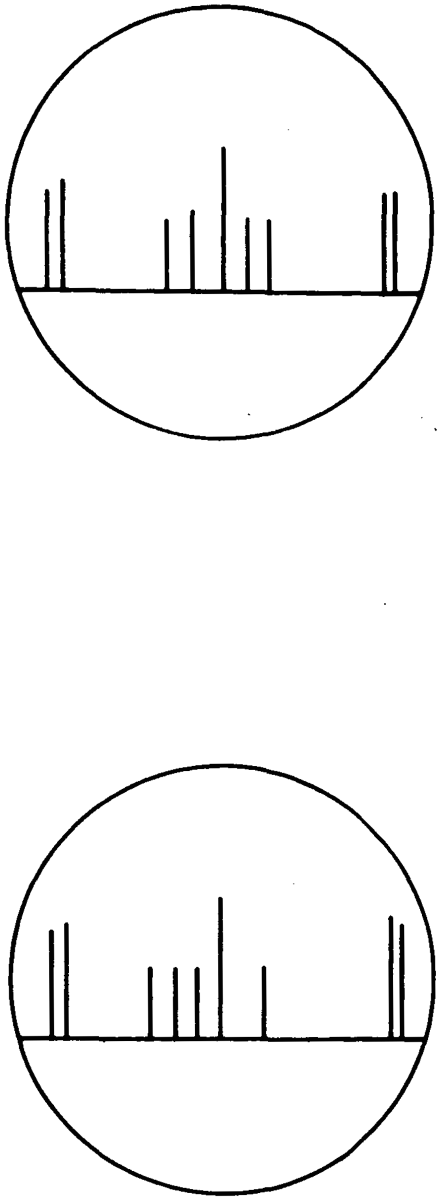
False lock or sideband lock can be detected by monitoring the system spectrum display and the 1-MHz biased doppler frequency. The spectrum display should indicate symmetrical sidebands when the system is properly locked to the carrier (Figure 3-28(A)). If the transceiver is locked to the 30-kHz or 70-kHz subcarrier, there will be an uneven number of sidebands above or below the carrier as shown in Figure 3-28(B).

Figure 3-29 is a typical plot of doppler offset versus time for Apollo 7 on revolution 1 over Texas. This figure shows the doppler variation experienced by a tracking station for an earth orbit pass. Station operators could detect sideband lock by comparing prepass predicted two-way doppler versus time for any pass with measured values obtained in real time. This can be observed by the ground tracking station on the 1-MHz bias doppler readout.

3. During the ascent propulsion system burn to depletion over Merritt Island on revolution 65, there was no ranging. Examination of data showed that the range receiver was not in lock between acquisition of signal, and final loss of signal and during keyhole. After keyhole, the lunar module transceiver locked to a ranging spur and remained that way until final station loss of signal. There was no attempt to reacquire the S-band uplink.

4. Lunar Module Transceiver False Lock and Acquisition Anomalies Laboratory Tests

   Preliminary evaluation of the lunar module transceiver false lock tests conducted on 30 April 1969 in the Electronic Systems Compatibility Laboratory facility showed a definite correlation to the Honeysuckle 29 anomalies. Conditions as nearly representative of those occurring during the Honeysuckle 29 pass were simulated.



A - Normal Carrier Lock

B - Up-link lock to 30 kHz
upon sideband

FIGURE 3-28 SPECTRUM DISPLAY FOR CARRIER AND SIDEBAND LOCK

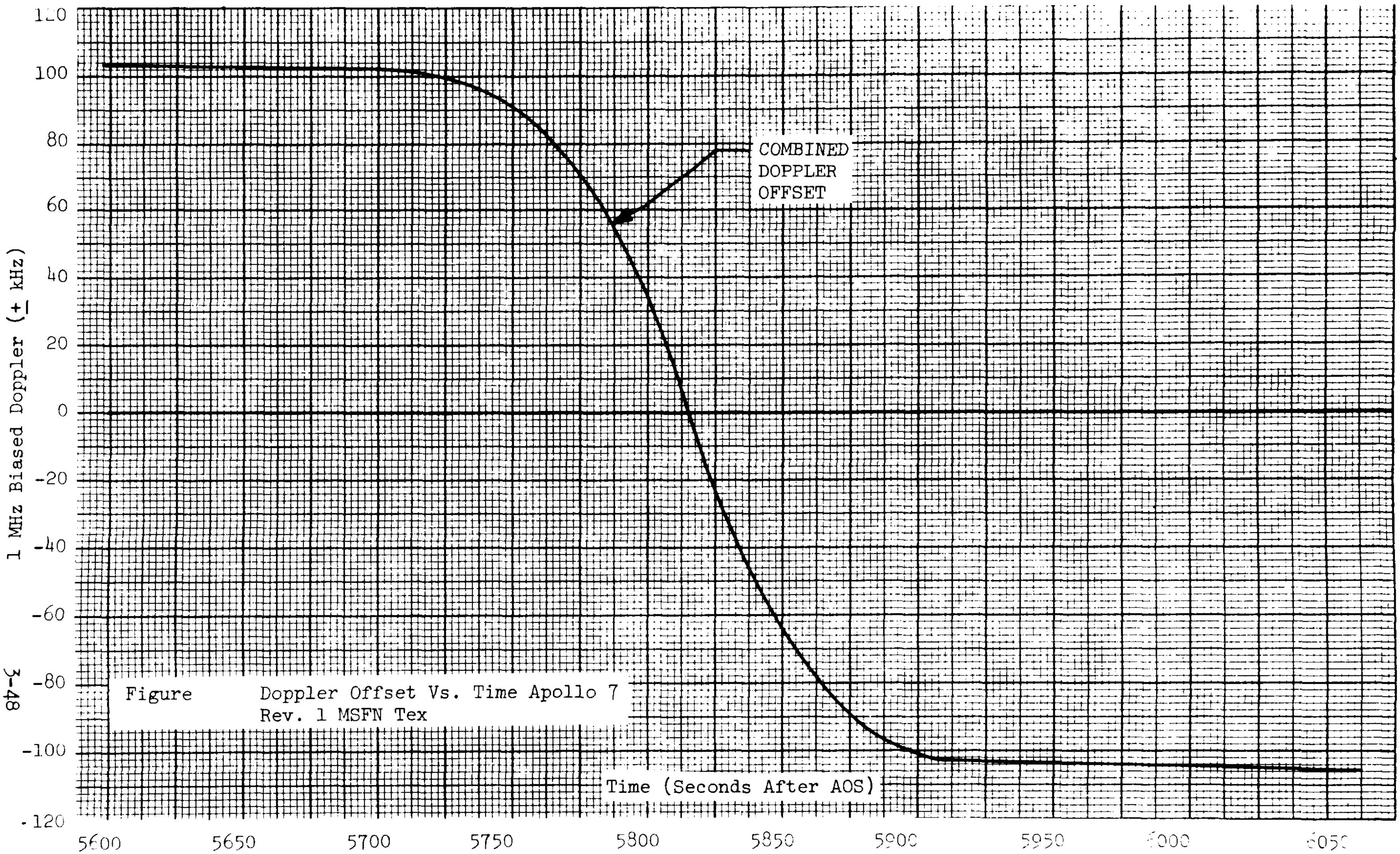


FIGURE 3-29 DOPPLER OFFSET VS. TIME APOLLO 7 REVOLUTION 1 MSFN TEX

The test results indicate a susceptibility of the transceiver to drop carrier lock and lock up the 30-kHz upvoice side band when the transceiver is subjected to drops in total power of 35 dB. The drop of 35 dB did not approach the normal receiver phase threshold. (In mode 6.2 the uplink received carrier power was approximately -55 dBm). Drops of 20 dB, 30 dB, and 40 dB were introduced. No loss of lock was experienced until the 40-dB transient was introduced. The receiver then shifted to the 30-kHz side band. After several tests, the level was adjusted to 35 dB and appeared to be the approximate threshold at which the receiver lost lock and switched to the 30-kHz sideband. This step function level was equal to the probable null depth between the 85-foot antenna main lobe and the first side lobe.

The drop of 35 dB from the input carrier power level of -55 dB resulted in a power level into the receiver of -90 dBm which was well in excess of the carrier tracking threshold under steady state conditions. Voice modulation of the uplink was performed and amplitude variations in the downlink received power were observed to be the same as the Honeysuckle revolution 29 data. However, this test transceiver did not jump back to the carrier as the lunar module-3 transceiver apparently did.

Manned Space Flight Network and flight crew procedures should be evaluated to determine if techniques can be developed to minimize the effects of false locks on lunar communications. Manned Space Flight Network acquisition procedures should also be reviewed to determine what changes are required to minimize false uplink acquisitions.

3.6 Command And Service Module Command Discrepancy Evaluation

The command and service module communications system performance after the lunar module operations was satisfactory. However, from about 108:43:03 to 118:46:53 GET, the sites could not confirm acceptance of commands to the command and service module. During most of this period, uplink and downlink received carrier power levels were adequate for spacecraft command acceptance. This discrepancy was eliminated when the crew recycled a spacecraft updata link switch (S-39).

The lack of command capability that existed from the Ascension site loss of signal on revolution 69 through the Carnarvon revolution 75 has been thoroughly analyzed with regard to the S-band ground system and uplink and downlink performance. For stations that commanded, command encoding, command retransmissions, and uplink command spacing were verified. In addition, the updata link status word was analyzed for five states: standby, message acceptance pulse present (MAP), test word A, test word B, or power off in the updata link.

For Ascension revolution 69, command encoding was proper. The updata link status word indicated the proper MAP or standby status as determined in the mission by the USB 642B computer. The one anomaly found was an excessive time increment (about 1.2 seconds) between successive words in multiward commands for the sixth, seventh, and eighth uplink commands through ascension. The specified time for the MAP wait period for Apollo 9 was approximately 360 $\pm$ 20 milliseconds. The measured time for the MAP wait period varied from site to site and for different time periods within a single site. From an evaluation of existing data, this time varied from 390 to 465 milliseconds. Even though this is unusual ground systems performance, there was no abnormal performance caused by the varying wait period. In each case, a MAP was generated by the spacecraft and received on the downlink telemetry. In summary, no anomaly occurred during Ascension revolution 69 within the ground systems that could cause loss of command capability for succeeding passes.

The last valid MAP received from the spacecraft until the updata link logic was reset manually was at Guam during revolution 69 on the first word of the first command. No further commands were accepted until the logic was reset at Carnarvon during revolution 75. During the first part of the Guam pass, signal strength on the uplink was sufficient for commands to be accepted by the command and service module. Encoding and transmission were also proper, indicating the spacecraft was unable to receive the command, generate the MAP, or perform the uplink commanded function.

Commanding was not possible during Mercury coverage of revolution 69, 70, and 71 due to improper uplink lock. In each revolution, Mercury was in a false lock situation that would not have allowed command acceptance by the command and service module updata link logic.

An analysis of Ascension and Guam revolution 69 phase shift keyed (PSK) command information showed badly distorted waveforms occurring within command transmissions. This distortion was in the form of a dc shift occurring when two successive transitions carried dissimilar information. This distortion apparently did not hamper the spacecraft as commands were received and validated with this condition present. The distortion for a pattern of 1's and 0's was apparent in phase shifting of the wave form. During the commanding, the wave form was approximately 90 degrees out of phase. In addition, the zero pattern was approximately 20 percent deviated from the normal pattern. The PSK is normally all ones (5 volt deviation) when no commanding is in process. However, a pattern of ones and zeros decodes to the proper octal command when commanding takes place. For the first shift from 1 to 0, the wave form was 20 percent deviated (0 volts or ground being a zero). As the ones and zeros shift continued in completing the command, the deviation from zero decreased to approximately 5 percent deviation. PSK at times other than actual commanding was normal. However, marginal operation could have been expected with the unusual PSK as described.

As shown in Table II, sufficient commanding was accomplished during effective radio frequency coverage to indicate that the updata link was not performing satisfactorily. The only time the logic voltage went to zero was when the spacecraft logic was reset. This was an expected indication.

The following summarizes the Table II results:

Commands Uplinked	86
MAP Mode	74
Override Mode	12
Accepted	17½
Rejected	69
*Operable Commands (Exc. Ascension 69, Carnarvon 75)	42
Number of passes (Exc. Ascension 69, Carnarvon 75)	19
Number of separate stations	11

*sufficient radio frequency uplink signal strength, proper lock on uplink.

NOTES:

1. DURING THE PERIODS OF COMMAND TRANSMISSIONS THE UPLINK AND DOWNLINK RECEIVED CARRIER POWER WAS ADEQUATE TO PROVIDE COMMAND AND COMMAND VERIFICATION CAPABILITIES.
2. DURING THESE TIME PERIODS THE UPLINK CARRIER POWER WAS NOT ADEQUATE TO PROVIDE COMMAND CAPABILITY, THEREFORE, MAPS CANNOT BE EXPECTED
3. DURING THESE TIME PERIODS THE DOWNLINK CARRIER POWER WAS NOT ADEQUATE TO PROVIDE RELIABLE TELEMETRY PERFORMANCE, THEREFORE, MAPS CANNOT BE EXPECTED.
4. DURING THESE TIME PERIODS TELEMETRY DECOM OUT OF LOCK, THEREFORE, MAPS CANNOT BE RECEIVED.
5. DURING THESE TIME PERIODS UPLINK MODULATION NOT ON. NO COMMAND CAPABILITY.
6. DURING THESE TIME PERIODS THERE WAS APPARENT FALSE LOCK OF THE CSM TRANSPONDER PREVENTING COMMAND CAPABILITY.

CMD SENT:
M = MAP MODE
O = OVERIDE

STA. REV.	CMD SENT	MAP REC.	R.F. UP DBM	R.F. DN.	CMD. HIST.	REMARKS
ACN 69	13-M 6-0	11 5	-90 MIN -66 MAX	-110 MIN -86 MAX	YES	FROM 108:36:50 TO 108:37:35 SEE NOTE 5 FROM 108:37:30 TO 108:39:20 SEE NOTES 2 & 3 FROM 108:37:30 TO 108:39:50 SEE NOTE 4 FROM 108:39:40 TO 108:43:30 SEE NOTE 1
GWM 69	3-M 5-0	1/2 0	-125 MIN -101 MAX	-130 MIN -121 MAX	YES	FROM 109:21:00 TO 109:22:50 SEE NOTE 3 FROM 109:21:30 TO 109:24:10 SEE NOTE 2
MER 69	10-M 1-0	0 0	-110 MIN -75 MAX	-100 MIN -72 MAX	YES	FROM 109:36:00 TO 109:37:30 SEE NOTE 1 FROM 109:37:30 TO 109:42:30 SEE NOTE 6
ACN 70	7-M 0-0	0	-100 MIN -74 MAX	-105 MIN -100 MAX	YES	FROM 110:10:15 TO 110:14:00 SEE NOTE 1 FROM 110:14:00 TO 110:17:00 SEE NOTE 3
GWM 70	4-M 0-0	0	-85 MIN -56 MAX	-100 MIN -72 MAX	YES	FROM 110:52:15 TO 110:59:45 SEE NOTE 1
MER 70	5-M 0-0	0	-90 MIN -71 MAX	-110 MIN -70 MAX	YES	FROM 111:11:00 TO 111:16:45 SEE NOTE 6
CYI 71	1-M 0-0	0	-92 MIN -85 MAX	-118 MIN -112 MAX	YES	FROM 111:52:30 TO 111:53:30 SEE NOTE 1
GWM 71	3-M 0-0	0	-89 MIN -71 MAX	-115 MIN -90 MAX	YES	FROM 112:28:30 TO 112:30:30 SEE NOTE 1 FROM 112:30:30 TO 112:31:10 SEE NOTE 3
MER 71	1 M 0-0	0	-85 MIN -72 MAX	-82 MIN -76 MAX	NO	SEE NOTE 6 FOR ENTIRE PASS
CYI 72	2-M 0-0	0	-100 MIN -71 MAX	-115 MIN -85 MAX	YES	FROM 113:25:00 TO 113:29:00 SEE NOTE 1
MAD 72	4-M 0-0	0	-105 MIN -70 MAX	-118 MIN -86 MAX	YES	FROM 113:30:00 TO 113:31:30 SEE NOTE 1
MER 72	NO CMD SENT		MIN MAX	MIN MAX	NO	NO DATA PROCESSED
VAN 73	1-M 0-0	0	-80 MIN -66 MAX	-98 MIN -82 MAX	YES	FROM 114:52:00 TO 114:56:30 SEE NOTE 1
CYI 73	4-M 0-0	0	-100 MIN -80 MAX	-130 MIN -102 MAX	YES	FROM 114:57:00 TO 115:00:00 SEE NOTE 3 FROM 114:58:40 TO 115:10:00 SEE NOTE 4
MAD 73	NO CMD SENT		-85 MIN -71 MAX	-120 MIN -80 MAX	NO	FROM 115:03:00 TO 115:05:40 SEE NOTE 1
HSK 73	NO CMD SENT		-100 MIN -66 MAX	MIN MAX	NO	FROM 115:41:30 TO 115:44:15 SEE NOTE 1
ANG 73	NO CMD SENT		-80 MIN -56 MAX	MIN MAX	NO	SEE NOTE 1 FOR ENTIRE PASS
CRO 73	NO CMD SENT		-90 MIN -66 MAX	MIN MAX	NO	FROM 115:33:30 TO 115:34:45 SEE NOTE 3
MIL 74	1-M 0-0	0	-90 MIN -66 MAX	-110 MIN -88 MAX	YES	FROM 116:18:40 TO 116:20:20 SEE NOTE 1
BDA 74	NO CMD SENT		-100 MIN -75 MAX	MIN MAX	NO	FROM 116:20:45 TO 116:23:15 SEE NOTE 1
CRO 74	1-M 0-0	0	-90 MIN -71 MAX	MIN MAX	NO	NO DATA PROCESSED
VAN 74	NO CMD SENT		-95 MIN -74 MAX	MIN MAX	NO	NO DATA PROCESSED
ANG 74	1-M 0-0	0	MIN MAX	MIN MAX	YES	NO DATA PROCESSED
CYI 74	NO CMD SENT		-76 MIN -66 MAX	MIN MAX	NO	FROM 116:31:45 TO 116:34:50 SEE NOTE 1
MAD 74	NO CMD SENT		-95 MIN -56 MAX	MIN MAX	NO	FROM 116:37:00 TO 116:39:30 SEE NOTE 1
HSK 74	3-M 0-0	0	-91 MIN -66 MAX	MIN MAX	YES	FROM 117:15:45 TO 119:45:00 SEE NOTE 1
MER 74	NO CMD SENT		-100 MIN -71 MAX	MIN MAX	NO	NO DATA PROCESSED
MIL 75	NO CMD SENT		-66 MIN -56 MAX	MIN MAX		FROM 117:53:30 TO 117:56:00 SEE NOTE 1
BDA 75	6-M 0-0	0	-86 MIN -56 MAX	MIN MAX	YES	FROM 117:56:00 TO 117:59:45 SEE NOTE 1
VAN 75	1-M 0-0	0	-92 MIN -74 MAX	MIN MAX	YES	SEE NOTE 3 FOR ENTIRE PASS
CYI 75	2-M 0-0	0	-66 MIN -56 MAX	-100 MIN -88 MAX	YES	FROM 118:05:00 TO 118:08:00 SEE NOTE 1
CRO 75	1-M 0-0	1	-85 MIN -66 MAX	MIN MAX	YES	FROM 118:39:50 TO 118:46:56 SEE NOTE 1
HSK 75	5-M 0-0	3 M	MIN MAX	MIN MAX		FROM 118:08:00 TO 118:11:00 SEE NOTE 1

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APOLLO 9
COMMAND STATUS
REVOLUTION 69 TO 75

SIZE D

The override mode is employed when sufficient commands are rejected by the spacecraft near acquisition or loss of signal and during other low signal strength periods. The override mode allows command uplink to take place without waiting for MAPS. The mode is switch selectable on any console having command capability at Mission Control Center. Using the override mode also allows commanded function performance in the absence of a downlink MAP for multiword real-time commands.

TABLE III COMMUNICATIONS EVENTS

	EVENT	TIME	REMARKS	DISCUSSED FURTHER IN TEXT - SECTION NUMBER
Launch Phase	Launch	00:00:00(16:00:00 GMT)	S-band voice varied from good to unusable due to handover and acquisition problem. No VHF voice from MIL after launch plus 3 minutes. Cause was insensitive VHF receiver MIL.	II A
Insertion To LM Activation And Check-out	Backup Voice Check	00:50:00 (CRO 1)	Back-up downvoice was received good quality and good intelligibility.	II B
	LM Activation, VHF	Between stations	Voice performance satisfactory.	
	LM Activation, S-Band	43:36:52 (Actual MAD 28)	Voice performance satisfactory.	
	LM Steerable Check	(44:05:00) (CRO 28)	Scrubbed.	
	MSFN Relay Check	(44:25:00) (HSK 28)	Rescheduled from 44:22 to 44:32 and then scrubbed.	
LM Activation And Check-out	LM Secondary S-Band Check	44:52:36 (ANG 29)	Acquisition problems. Insufficient data to properly evaluate. Checks rescheduled for CRO 32.	II C
	PLSS Checkout	45:38:39	Satisfactory.	
	First DSE Dump of LM data	(Actual CRO 29)	No voice on dump (planned). LM data quality "Fair" - but usable. CSM one way relay check scheduled here was scrubbed.	
	LM Two-Way Relay	46:00:16 (MER 29)	Successful after overcoming initial difficulty in adjusting LM VOX sensitivity.	
	First TV Pass	46:27:16 (Actual MIL 29/30)	TV good. Voice problem-site received good LM USB downvoice, but voice was not remoted to Houston.	
	Mode 7 Communications Check	(46:35:00) (planned BDA 30)	Scrubbed.	
	Mode 8 Communications Check	(46:40:00) (planned VAN, CYI 30)	Scrubbed.	
	LM Backup Down Voice Check	50:30:01 (Actual CRO 32)	Site did not receive back-up downvoice.	
	LM Backup Down Voice, Final	50:46:57 (Actual HSK 32)	Check was accomplished, but not entirely successful. Back-up downvoice received at the site was very weak and of short duration.	
	CM One Way Relay	72:06:20 (Actual BDA 46)	Slight echo, but readable. Relay check ok.	
EVA Activity	EVA Start	72:55:00 (Actual HSK 46)	Down voice good. Uplink voice problem due to station configuration problems.	II D
	EVA End	73:48:00	Down voice good.	
	Second TV Pass	74:57:25 (Actual GDS, MIL)	TV & voice good.	
Rendezvous Activity	CSM/LM Undocking	92:38:41	Communications performance satisfactory. Voice good.	
	LM/CSM Docking # 2	99:03:00	Communications performance satisfactory. Voice good.	II E

TABLE III COMMUNICATIONS EVENTS
(CONCLUDED)

	EVENT	TIME	REMARKS	DISCUSSED FURTHER IN TEXT - SECTION NUMBER
CM Operations (Post LM)	HGA Check (CRO)	193:07:58 (Actual CRO 122)	Satisfactory performance. Good voice.	II F
	HGA Check (HAW)	193:35:06 (Actual HAW 122)	Satisfactory performance. Excellent voice.	
	SPS 8 Deorbit Maneuver	240:31:13 (Actual HAW 151)	Voice satisfactory.	
Re-entry Phase	CM/SM Separation			II G
	Begin Blackout	240:47:00	240:37:21 - Predicted start of blackout. Voice as predicted.	
	End Blackout	240:50:42	240:50:45 - Predicted end of blackout. Voice as predicted.	

TABLE IV SIGNIFICANT REPORTED COMMUNICATIONS DISCREPANCIES

DISCREPANCY	STATION/REV	REMARKS	DISCUSSED FURTHER IN TEXT - SECTION NUMBER
Launch			
Poor Telemetry	MIL 01	ASPO requested special investigation.	II A IIIA
AUX OSC mode during 1st handover	MIL/GBM 01	Failure of GBM to acquire uplink caused spacecraft to switch to auxiliary oscillator mode.	II A
Premature handover attempt	GBM 01	Operator error caused transmitter cutoff 30 seconds early.	II A
Insertion			
Backup communications check	CRO 01	Voice received by station and recorded, not remoted.	II B
Loss of VHF downlink	ANG/VAN 13	VAN problem appears to be erratic performance of the VHF antennas. ANG received only S-band voice. Next station received excellent VHF voice.	
Poor Telemetry	MIL 15	ASPO requested special investigation.	III A
Early LOS-No reacquisition	VAN 17	VAN LOS occurred four minutes early. Did not reacquire.	II B
DSE dump with tones present	GYM 16	Tones in the voice spectrum were present during playback. Predetection bandwidth determined to be too narrow.	II B
Poor Telemetry	MIL 17	ASPO requested special investigation.	II A
LM Activation			
LM secondary S-band check	ANG 29	Voice breakup, could not maintain USB lock.	II C
No S-band voice with 1st TV pass	MIL 30	During mode 10 TV transmission no S-band down voice was remoted.	II C
1st LM two-way relay	MER 29	Originally scheduled TEX, Rev. 29. Voice communications broken	II C
LM frequency acquisition	HSK 29	LM transceiver locked to sideband.	III E
No LM ranging (USB)	GDS 31/32	Station reported unable to obtain ranging for 2 Revs. Finally obtained ranging after switching from 2 KW output to 450 Watt output.	III E
USB loss of lock	VAN 44	VAN was unable to maintain USB lock during pass. Sea storm attributed to be a contributing factor.	
EVA			
Uplink voice loss-EVA	Stateside 46/47	Only one uplink voice transmission answered from egress through ingress. Ground configuration problem.	II D
No LM ranging (USB)	GYM 63	No LM ranging during LM power down phase. LM configuration had some circuit breakers pulled.	
Loss of downvoice subcarrier	TEX 63	LM voice subcarrier may have been lost due to LM power down previous to pass. Total LM configuration unknown.	
Invalid ranging-APS burn	TEX 64	Station unable to obtain valid ranging during APS burn. Used improper ranging mod index.	III E
CSM Operations			
Command capability loss to CSM	ALL 69	Command accept by CSM lost for approximately 10 hours. Regained by crew resetting UDL.	III F
Spacecraft command reject-HGA	CRO 122	Commands not verified at site during operation of High Gain Antenna. One command was transmitted prior to obtaining uplink. Three other command maps were not received because the station PCM decommutator was out of lock.	

APPENDIX B

A. Apollo 9 Communications Objectives

1. The mission required detailed test objectives related to communications were P20.21 and P20.22 prior to Apollo 9. S20.23 was demonstrated during revolution 122 as an added flight plan task.

Definition:

P20.21 LM/MSFN S-band communication performance - demonstrate the LM/MSFN operational S-band communication subsystem capability.

P20.22 LM/CSM/MSFN S-band/VHF compatibility - demonstrate LM/CSM/MSFN/EVA operational S-band and VHF communication compatibility.

S20.23 CSM High Gain Antenna - demonstrate CSM S-band high gain antenna operation.

2. P20.21

The status of each communications check within this objective is listed in the Communications Events Table, Table III.

The overall objective was successfully demonstrated. The lunar module steerable antenna check and LM/MSFN relay check were deleted during the mission. Although completed, the lunar module backup voice check was not completely successful.

3. P20.22

The overall results of each communications check from this detailed test objective are listed in the Communications Events Table, Table III. The overall objective was successfully demonstrated.

4. P20.23

This test was successful and the results are listed in the Communications Events Table.

APPENDIX C

References

1. Apollo 9 MSFN-LM PRN Ranging Anomaly (Test Results). Lockheed Electronics Company (AD 63-218-22-362-21-18) Apr. 17, 1969.

2. Apollo Preliminary Evaluation Report. Lockheed Electronics Company, Mar. 25, 1969.

3. Apollo 9 CM-FM Mode 1 Tones. (Lab. Test) Lockheed Electronics Company, Mar. 10, 1969.

4. Apollo 9 Flight Plan AS 504/CSM 104/LM-3. Dec. 11, 1968.

5. Communications System Flight Evaluation Program Plan for Apollo 9 Mission. ISD EB-69-3145-U, Feb. 4, 1969.

6. Gardner, Floyd, M.: Phase Lock Techniques. John Wiley and Sons, Inc. 1966. (for acquisition and false lock discussion).

7. Performance Testing Of Stelma VOGAA-1 Voice Gain Adjusting Amplifier. Lockheed Electronics Company (AD 63-218-22-362-21-13), May 1, 1969.